VTT Technical Research Centre of Finland

NEXT-ITS 2 Evaluation Report

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1 Executive Summary

The NEXT-ITS 2 project contains a number of measures deployed on the NEXT-ITS 2 corridor and in traffic management centres in order to move from local traffic management towards coordinated and cross-border management of the whole corridor. The evaluation performed has covered the services deployed or enhanced by the road authorities involved during the period 2015-2017, also including some measures completed fully in early 2018. The objective has primarily been to evaluate the costs and impacts of the services deployed i.e. how the measures contribute to reduction in travel time, accidents and emissions from road transport.

The total length of the NEXT-ITS corridor itself is about 3 000 km, but the impacts of the NEXT-ITS 2 measures cover a much larger road network, about 25 000 km. This is due to the fact that many measures focus on improving the effectiveness and quality of traffic centre operations. In the participating countries, the traffic management centres of the road authorities provide their services on the whole comprehensive TEN-T network, and even wider, on the whole main road network including the arterials to the bigger cities connected by the main road networks.

Hence, in order to cover all benefits of the measures in a fair way, also the contribution of the NEXT-ITS 2 measures to solving transport problems outside the actual corridor have been taken into account. As the contribution of the measures to the effectiveness of existing ITS services varies by measure and type of service, the road network affected by the service had to be separated in several different sub-networks in some countries to be able to estimate the impacts of NEXT-ITS 2 as correctly as possible. In these cases, the impacts were first calculated separately for each sub-network, and then summed up for all networks impacted by NEXT-ITS 2 measures in the countries.

The evaluation was carried out as an ex-ante evaluation, taking the estimated impacts of the measures into account. The assessed impacts of the deployed services on the NEXT-ITS 2 corridor and networks are based on experience from the impact assessment studies available for the traffic management and information services deployed and enhanced via the measures implemented in 2015-2017. While taking into account the results from existing studies, especially from regions outside NEXT-ITS, the results were adapted somewhat in order to consider the differences in traffic and environmental conditions between the ones in the impact studies and the ones prevailing on the NEXT-ITS 2 networks.

The total estimated effects of the services are considerable, about 490 000 vehicle hours driven less and circa 135 000 vehicle hours less spent in congestion annually. About three severe accidents and 11 000 tonnes of CO_2 emissions are avoided annually due to NEXT-ITS 2. The total value of the annual benefits in 2017 will be circa 15 Million €, which can be compared to the implementation costs of circa 33 million € including VAT and thereby comparable to the benefits (the costs without VAT amount to almost 27 Million €). As the annual operation and maintenance costs will be in the order of 3 Million €, the NEXT-ITS 2 can be assessed to be socio-economically profitable.

The sensitivity analysis shows that the benefits calculated vary a lot dependant on the most important input parameters. However, it can be concluded that even with conservative estimates, NEXT-ITS 2 has a positive net impact.

It needs to be pointed out that the effect estimates are based on a desk-top analysis, which needs to be compared to the actual statistics from the NEXT-ITS 2 corridor and the national networks affected. Such an ex-post evaluation should be carried out when the services are fully deployed and in use, for instance in 2019.

However, it is clear that the effects of the services are extremely difficult to measure especially in this era of technology disruption due to connected and automated driving, the internet of things, digitalisation, etc. Thereby, even the ex-post evaluation needs to be accompanied with a desk-top analysis similar to the ex-ante assessment reported here.

Overall, the general conclusion is that the ITS investments are profitable for the society.

2 Description of the Problem

2.1 Issues Addressed

The main objective of the NEXT-ITS 2 has been to improve the network performance - in terms of efficiency, reliability, safety and environmental impact - of the Northern part of the Scandinavian-Mediterranean CEF corridor from Oslo and the Finnish-Russian border in the north via Copenhagen, Hamburg, and Bremen to Hanover in Germany. Cross-border continuity of traffic management services has been targeted through coordinated deployment of Traffic Management services and major upgrades of Traffic Management centres.

The NEXT-ITS 2 action addresses “Europe-wide traffic management systems to optimise traffic operations on the core network” by the deployment of core European traffic management services on the Northern part of the Scandinavian-Mediterranean corridor, and the coordination of management and control strategies for centres along the corridor. The action further addresses the deployment of ITS services that enhance road safety on the corridor, with particular attention on urban-interurban intersections where long-distance traffic merges with local commuter traffic.

During the last decade the traffic load has increased considerably on the corridor, especially the presence of heavy goods vehicles. The increased traffic load and extensive presence of HGVs make the corridor and core network vulnerable to disturbances. The road network of the sparsely populated areas of Northern Europe offers limited possibilities for alternative routes and large parts of the network is subject to recurring hard weather conditions, particularly in wintertime.

The measures included in NEXT-ITS 2 have been chosen in order to fill the gaps concerning coverage, accessibility, dissemination, quality and content of the core traffic management services as well as to improve the cost-efficiency in the operation of traffic management.

In addition, the project has contributed to know-how development and has actively engaged in the work aiming at European harmonization and knowledge building.

2.2 Site description

The NEXT-ITS 2 corridor forms the Northern part of the Scandinavian–Mediterranean Corridor. (Figure 1).
The corridor connects Northern Europe with Western and Southern European transport networks. It offers the primary road transport connections between Western/Central Europe and Norway and the St. Petersburg region of Russia. It links the major urban centres and ports of Scandinavia and Northern Germany with the industrialised high production regions of Southern Germany, Austria and Northern Italy etc.

As basic network for the assessment of the deployment KPIs of NEXT-ITS 2 measures, the comprehensive TEN-T Network has been used. The measures of NEXT-ITS 2 address mainly the Northern part of the Scandinavian-Mediterranean Corridor, but influence also the adjacent road network to the corridor and – in particular where general improvements and enhancements of traffic centres are carried out – larger parts of the main road network.

Figure 1 - The Northern part of the Scandinavian–Mediterranean Corridor.

2.3 Research Questions

To evaluate the impacts, costs and benefits of the services deployed along the corridor and networks. In particular, how much the NEXT-ITS 2 measures contribute to reduction in travel time, accidents and CO_2 emissions from road transport.

2.4 Objectives for the Evaluation

The purpose of the evaluation was to evaluate the deployment/coverage as well as the impacts, costs and benefits of the systems and services deployed in NEXT-ITS 2.

3 Description of the ITS Project

3.1 ITS Selection Rationale and Objectives

The main objective of the NEXT-ITS 2 has been to improve the network performance - through coordinated implementation of core traffic management services.

The measures included in NEXT-ITS 2 have been chosen in order to fill the gaps concerning coverage, accessibility, dissemination, quality and content of the core traffic management services as well as to improve the cost-efficiency in the operation of traffic management. (See also 2.1. Issues addressed).

3.2 Status of the Project

The NEXT-ITS 2 project is finalized per end of 2017. The project period was 2015-2017.

A few deployments which were part of the original plan will be completed later in 2018, please refer to the details in the annexes for country specific postponements.

3.3 Systems and Technologies Applied

The NEXT-ITS 2 deployments consist of seven measures (M1-7):

Measure 1 – TMC renewal and adaptation to corridor management and control systems, Finland

Measure 1 aims at updating the systems at the traffic management centre and will thus improve the operation and performance of the already installed road side equipment as well as existing traffic information and traffic management services.

Measure 2 – Motorway Control System (MCS), Sweden

Measure 2 includes reinvestment of MCS system and stop detection radar as well as replacement of variable direction signs and development of a new control system for MCS.

Measure 3 - Integrated Traffic Management, Sweden

Measure 3 aims at establishing a common infrastructure asset database and platform for road and rail infrastructure asset data.

Measure 4 - New Traffic Management Centre in “The Traffic Tower” in Copenhagen, Denmark

Measure 4 includes a new traffic management centre and a road weather management decision support system.

Measure 5 - Traffic Management Plans and Ramp Metering Systems, Germany

Measure 5 aims at establishing Traffic Management Plans and Ramp Metering Systems along the Scandinavian-Mediterranean corridor in Northern Germany.

Measure 6 - Traffic Centre Schleswig-Holstein, Germany

Measure 6 addresses upgrading and enhancement of the traffic management centre in Schleswig-Holstein. The measure will particularly focus on improvements of the basic data, data processing, data exchange and integration of further systems into the centre.

Measure 7 Improve the DATEX-node to meet ITS Directive Action C, Norway

Measure 7 aims to make use of a national DATEX-II node for traffic information exchange in order to improve the distribution of Safety related traffic information (action C) on the TEN-T road network in Norway. The DATEX-II node operates 24/7 and helps service providers to identify relevant messages to be distributed on their services.

(Measure 7 is not part of the Grant Agreement, but Norway is a formal partner of NEXT-ITS 2)

Each measure (M1-M7) contains deployment efforts including one or more of the implementation elements defined for the project:

- Data and service management: Implementation and upgrade of facilities, software and databases at Traffic Management Centres enabling service integration (M1, M2, M3, M4, M5, M6, M7)
- Development and implementation of Traffic Management Plans (M4, M5)
- Traffic Management Upgrade: Update of road side control software to enable service integration (M1, M2, M3)
- Traffic Management Upgrade. Implementation and update of Road Side information panels for driver information and control (M3, M5)
- Data fusion and data quality control at Traffic centres (M4)

The measures are described in detail in the annexes.

3.4 ITS Deployment Status (Deployment KPIs)

The coverage/deployment KPIs for the NEXT-ITS 2 in the end of 2017 show the change in coverage of ITS services due to the measures implemented during NEXT-ITS 2 (for Comprehensive TEN-T network, see explanation below).

Several NEXT-ITS 2 measures and deployments, e.g. upgrading of Traffic Centre capacity and improved travel time services, benefit a much larger network than the NEXT-ITS corridor only due to the nature of the services, by e.g. improving the content, quality and accessibility of the service as well as the area covered by the service.

It is important to note that several deployments are primarily focussing on *quality improvements* and not geographical extension of systems and services – which is also obvious when looking at the deployment KPIs. Thus, for the end of 2014 the coverage of several services already was 100%, but the measures implemented during NEXT-ITS 2 improved the services' quality generally or on specific sections where problems existed.

As basic network for the assessment of the deployment KPIs of the NEXT-ITS 2 measures, the Comprehensive TEN-T network has been used. This decision was taken in order to report deployment KPIs for a well-defined network, also taking into account the usage in e.g. the EU EIP platform evaluation activity and other European contexts.

The changes of the Deployment KPIs due to NEXT-ITS 2 measures from 2015 (31.12.2014) to the end of 2017 are stated in the tables per country below:

Finnish Comprehensive Ten-T Road network + few essential part of the main roads (Networks 1-4) 4637.7 km	**End of 2014 Length km**	**End of 2017 Length km**
Road weather monitoring	4637.7	4637.7
Fixed real-time traffic monitoring	4637.7	4637.7
Mobile/probe real-time traffic monitoring	-	-
Forecast and real-time event Information	0	238.1
Traffic Condition and Travel Time Information	-	-
Weather Information	4637.7	4637.7
Safety Related Traffic Information	-	-
Dynamic Lane Management	0	4.1
Variable Speed Limits	0	181.2
Incident Warning and Management	0	238.1
Ramp Metering	-	-
TMPs for Corridors and Networks	0	524

Swedish Comprehensive TEN-T Road Network 6391 km	**End of 2014 Length km**	**End of 2017 Length km**
Road weather monitoring	6391	6391
Fixed real-time traffic monitoring	6391	6391
Mobile/probe real-time traffic monitoring	0	558
Forecast and real-time event Information	6391	6391
Traffic Condition and Travel Time Information	6391	6391
Weather Information	-	-
Safety Related Traffic Information	6391	6 391
Dynamic Lane Management	0	18.5
Variable Speed Limits	-	-
Incident Warning and Management	6391	6391
Ramp Metering	-	-

Danish Comprehensive Ten-T Road network 1609 km	**End of 2014 Length km**	**End of 2017 Length km**
Road weather monitoring	1607	1609
Fixed real-time traffic monitoring	147	147
Mobile/probe real-time traffic monitoring	0	1609
Forecast and real-time event Information	-	-
Traffic Condition and Travel Time Information	147	1609
Weather Information	1607	1609
Safety Related Traffic Information	1607	1609
Dynamic Lane Management	-	-
Variable Speed Limits	-	-
Incident Warning and Management	1607	1609
Ramp Metering	-	-

Note: Only Traffic Condition information is available (1609 km) and not Travel Time information

Northern German Comprehensive Ten-T Road network 1780.8 km	**End of 2014 Length km**	**End of 2017 Length km**
Road weather monitoring	-	-
Fixed real-time traffic monitoring	-	-
Mobile/probe real-time traffic monitoring	-	-
Forecast and real-time event Information	-	-
Traffic Condition and Travel Time Information	1780.8	1780.8
Weather Information	-	-
Safety Related Traffic Information	1780.8	1780.8
Dynamic Lane Management	-	-
Variable Speed Limits	-	-
Incident Warning and Management[1)]	-	-
Ramp Metering	0	16
TMPs for Corridors and Networks	314.1	559.6

Norwegian Comprehensive TEN-T Road Network 4928 km	**End of 2014 Length km**	**End of 2017 Length km**
Road weather monitoring	-	-
Fixed real-time traffic monitoring	-	-
Mobile/probe real-time traffic monitoring	-	-
Forecast and real-time event Information	-	-
Traffic Condition and Travel Time Information	-	-
Weather Information	-	-
Safety Related Traffic Information	0	4928
Dynamic Lane Management	-	-
Variable Speed Limits	-	-
Incident Warning and Management[1)]	-	-
Ramp Metering	-	-
Traffic Management Plans for Corridors and Networks	-	-

An overview of measures and their relation to services is given in the table below.

Measure(s) per Country	Forecast and real-time event	Traffic Condition and Travel Time	Weather Information Service	Safety Related Traffic Information Service	Dynamic Lane Management	Variable Speed Limits	Incident Warning and Management	Ramp Metering	Traffic Management Plans for Corridors
Measure 1 – TMC renewal and adaptation to corridor management and control systems, FI	X		X		X	X	X		X
Measure 2 – Motorway Control System, SE	X	X		X	X		X		X
Measure 3 - Integrated Traffic Management, SE	X	X		X	X		X		X
Measure 4 - New Traffic Management Centre in “The Traffic Tower” in Copenhagen, DK		X		X			X		X
Measure 5 - Traffic Management Plans and Ramp Metering Systems, DE		X						X	X
Measure 6 - Traffic Centre Schleswig-Holstein, DE				X					
Measure 7 - DATEX-II improvements for Action C, NO				X					

Table 1. Measures and services included into NEXT-ITS 2 in each country.

Please refer to annexes for details on measures and services.

4 Evaluation

4.1 Research Questions Answered

This evaluation includes the estimated impacts, costs and benefits of the systems and services deployed as well as Key Performance Indicators for deployment.

4.2 Methods

The majority of the systems and services have been or will be launched in the end of 2017. A few systems and services will be operational in the first months of 2018. Therefore, it has not been possible to carry out an ex-post evaluation within the project period (2015 to 2017), but instead an *ex-ante evaluation* is performed with an assessment of all the defined KPIs (refer to section 3.4 and

4.5 for the selected KPIs). Based on this assessment, a consolidated corridor evaluation is presented in this report.

The optimal case would have been to have a real ex-post evaluation with the relevant evaluation data collected, but since the deployed measures have only just been put into operation, and since the project has to deliver an evaluation, the compromise has been to perform the ex-ante analysis including results from earlier relevant ex-post studies in the form of estimates of average effects on road users.

It is to a large extent a theoretical exercise and the estimates can be regarded as “best possible expert estimates” which are based on a large number of references.

Based on the European Evaluation Reporting Guidelines (developed within EU EIP) and as well the former EasyWay VIKING Guidelines, a step-wise methodology has been elaborated. Figure 2 (next page) tries to illustrate the approach taken and the reasoning behind:

Change in service quality due to the improved services obtained through the measures will lead to a change in use that will lead to a change in behaviour. The behavioural changes result in a change in impacts, i.e. the KPIs for impacts. Further, the extended coverage - indicated as a change in deployment KPIs – will result in a change in impact KPIs. Naturally penetration rate is also important, but the figure is to illustrate the principle.

A complimentary way could be to look at the change in the reference situation on the corridor. The reference situation is determined as the value of KPIs by the end of 2014 (/start of 2015). At the end of 2017, the KPIs are assessed again to determine the change. Note, when determining the reference situation, the values in the end of 2014 will have to be forecasted (or extrapolated) to describe the situation in the end of 2017, i.e. situation in end of 2017 if measures had not been deployed = “do nothing situation”. Note also, when assessing the KPIs at the end of 2017, it is a precondition that measures have been implemented in time to influence the KPIs. As described it is not possible to carry out an ex-post evaluation within the project period, but all the defined KPIs are assessed in order to present a corridor evaluation.

The methodology is illustrated in the figure 2

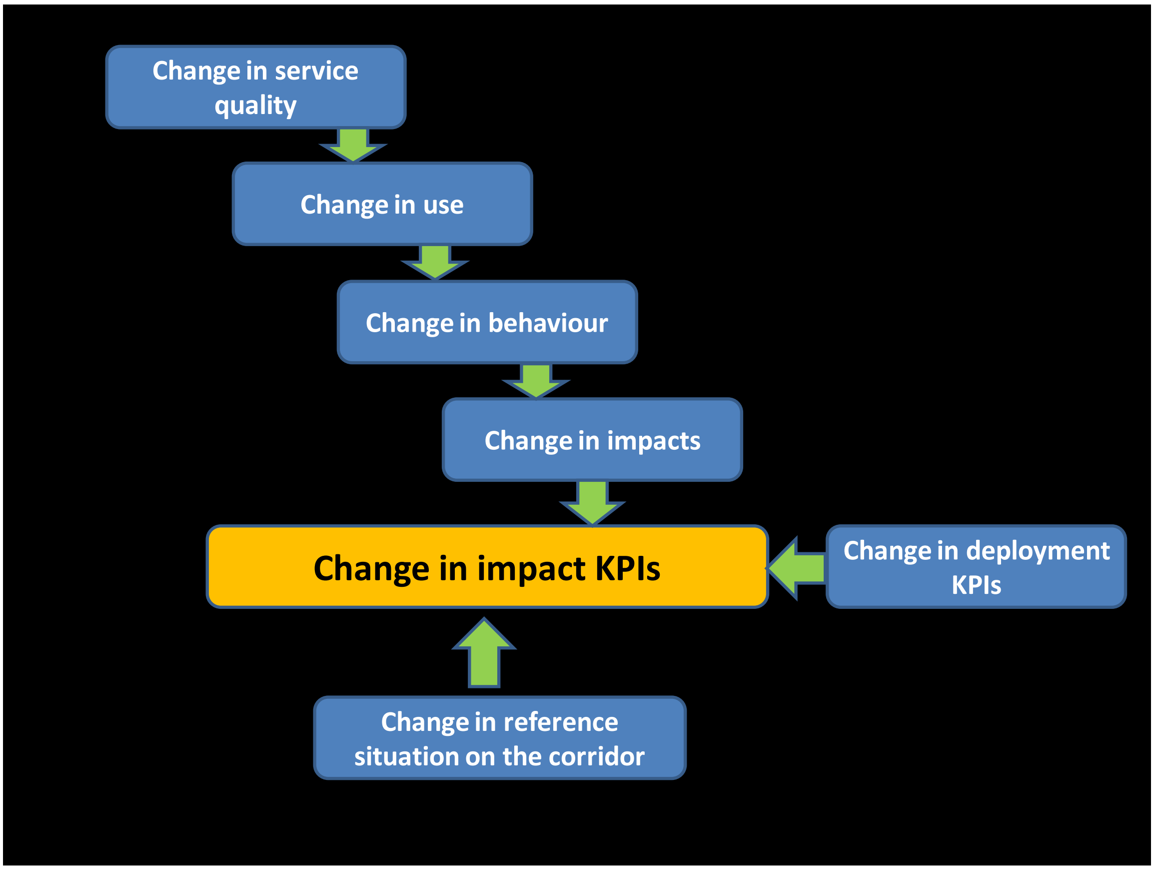

Figure 2 - NEXT-ITS Evaluation methodology

In order to estimate *the average effect of services on users on equipped/covered sections* of the NEXT-ITS 2 networks, the evaluation group has studied a large number of relevant references. (Refer to Annex 8).

The result is "the impact table" below on which the ex-ante evaluation is based.

KPI	Forecast and real-time event information	Traffic condition and travel time information	Safety related traffic information	Weather information service	Dynamic lane management	Variable Speed Limits	Incident Warning and management	Ramp metering	Traffic management plans
Veh hours driven	-0.4 %	-0.2 %	-0.5 %	-0.03 %	-0.03 %	-0.3 %	-2.0 %	-1.0 %	-0.3 %
Veh hours congestion	-1.0 %	-1.5 %	-1.5 %	-0.05 %	-0.3 %	-0.5 %	-10.0 %	-10.0 %	-3.0 %
Fatalities/ Fatal accidents	-0.5 %	0.0 %	-3.0 %	-3.0 %	-7.0 %	-8.0 %	-1.0 %	-3.0 %	0.0 %
Non-fatal injury accidents	-0.5 %	0.0 %	-3.0 %	-3.0 %	-7.0 %	-8.0 %	-1.0 %	-3.0 %	0.0 %
CO_2 emissions	-0.4 %	-0.2 %	-0.5 %	-0.03 %	-0.03 %	-0.3 %	-2.0 %	-1.0 %	-0.3 %

Table 2. Average effect estimates of NEXT-ITS 2 services on sections equipped or drivers covered

It is underlined that all numbers are *average estimates* and dependant on technical performance and service context, e.g. the operating environment and user acceptance.

Due to the nature of the measures where many traffic management centre upgrades and backbone IT-system improvements are included, the mapping of measures in relation to services (refer to section 3.4) is the basis for finding the “service bundle” in each network.

4.3 Timing and Type of Evaluation

The evaluation is an ex-ante evaluation, since most of the systems and services have recently been put into operation or will be shortly, in the end of 2017 or during the first months of 2018.

Hence, the evaluation is a part of the NEXT-ITS 2 project and it is conducted within the project period, 2015-2017.

4.4 Technical Performance

The technical performance of systems put into operation is generally at a good level. Some measures are not in (full) operation yet, so the overall technical performance of all measures in the NEXT-ITS 2 project is still to be investigated. However, the contracts and agreements are established to secure high technical performance and system uptime for the measures and for their related systems. The available preliminary analysis of technical performance of each of the seven measures are presented in the annexes 1 - 7. Statistics (e.g. system logs) in relation to down time / up time and the response times of the system (systems/services) will have to be followed up when all measures are in full operation.

4.5 Selected Benefit KPIs

The benefit KPIs were selected in the beginning of the project and are given below. These are described as the % change of vehicle hours driven, vehicle hours spent in congestion, fatal and injury accidents (or fatalities) and CO_2 emissions.

KPIs for impacts:

- (Vehicle kilometres driven)
- Vehicle hours driven
- Vehicle hours spent in congestion
- Fatal accidents/Fatalities
- Non-fatal injury accidents
- CO_2 emissions

“Vehicle kilometres driven” is used only in the benefit estimations. A percentage change is not estimated, because the average effect of services on the vehicle kilometres driven is ambiguous as the services could result in both more and less kilometres driven e.g. due to rerouting. It is anticipated however that the most likely effect is that more kilometres are driven, mainly as a result of the Traffic management services, in particular the traffic management plans including rerouting options.

The change in “Fatal accidents/Fatalities”: Finland and Sweden had to use number of fatal accidents in the benefit calculations due to the available statistics; all other countries are using the number of fatalities. The national unit values correspond this KPI selection.

4.6 Results

When calculating the impacts and benefits, the first step is to identify the networks which are affected (/influenced) by the services. Secondly, each network has to be analysed separately in terms of finding the network characteristics.

As an example, the networks influenced by Measure 1 - TMC renewal and adaptation to corridor management and control systems - are explained below:
In this Finnish case, the services vary in the impacted network and therefore, the full impacted network in Finland includes five different sub-networks, all of them having a different set of services implemented (i.e. different service bundles). The most advanced network includes all services improved by the measure (see table 1)), whereas the least advanced network benefiting from the measure includes real-time road weather information service only. The details concerning the networks and included services for each of them are presented in Annex 1.
Measure 1 has improved the traffic management, and thereby incident detection and overall traffic management and information. The impacts, however are expected to increase significantly in NEXT-ITS3 when the integration of various systems into the central traffic management system proceeds further.

The impacts have been calculated based on network statistics and related service bundles for all the measures.

Overall estimated impacts of all NEXT-ITS 2 measures

The total annual impacts of NEXT-ITS 2 services per country is shown in the table below.

Total annual impacts	Impacts in absolute numbers					
	DE	DK	FI	NO	SE	Total
Vehicle hours driven (1000/year)	-109.2	-110.2	-74.1	0	-197.3	**-491**
Vehicle hours spent in congestion (1000/year)	-54.5	-31.5	-6.3	0	-42.9	**-135**
Fatalities/Fatal accidents (number/year)	-0.009	-0.021	-0.056	-0.002	-0.021	**-0.11**
Injury accidents (number/year)	-0.158	-0.193	-0.998	-0.053	-1.046	**-2.45**
CO_2 emissions (kilo tonnes/year)	-1.93	-2.47	-1.52	0	-5.56	**-11.5**

Table 3: The total impacts of NEXT-ITS 2 services in the national networks (“-“ indicates reduction)

Overall, the estimated main impacts of NEXT-ITS 2 measures are seen in improved traffic flow, indicated with the KPIs vehicle hours driven (reduced by almost half a million vehicle hours per year), and vehicle hours spent in congestion (reduced by 135 000 vehicle hours per year). This is a result of the deployed measures, which aims mostly at improving traffic and incident management, and supporting it with the improved traffic information.

Fatalities and injury accidents are also reduced (by 0.11 and 2.45 respectively) and in total 11.5 kilo tonnes CO_2 emissions are saved due to NEXT-ITS 2 deployments. The low reductions in fatalities and injury accidents are due to the relatively modest effect estimates for accidents and fatalities and due to the “Effect enhanced” estimates are very cautious. Effect enhanced is the “additional” improvement of the service, e.g. based on the additional drivers benefitting from the service. (Details on effect enhanced in the various annexes on measures).

It is important to notice that some of the measures are deployed further during NEXT-ITS 3, and hence the overall benefits are expected to increase for those measures when the deployment proceeds.

5 Cost Benefit Analysis Results

5.1 Approach

The approach decided by the evaluation team is not to perform a full cost benefit analysis, but instead to compare a number of benefits (those related to the primary transport policy goals) to the costs.

Due to the nature of the deployments (to a large extent about upgrading traffic management centres) and the timing of the evaluation (evaluation is a part of the project and conducted before systems and services are in full operation), the impacts need to be estimated – and cannot be measured.

Assumptions on user behaviour and driver adherence are basis for the average impact estimates. Therefore, it is very important to underline that the methodology contains many uncertainties and should be regarded as “the possible” approach with the available information at hand.

It could be a good idea to define different scenarios for the future, e.g. based on penetration rate of services; but due to time limitations the approach has been to work with one average scenario for all measures. (Refer to section 4.2 also).

5.2 Costs

The total estimated costs of all NEXT-ITS 2 deployment measures are **27.7** million excl. VAT. These costs cover the implementation costs (investment, i.e. works costs).

For assessing the yearly costs of the measures, the investment costs have to be distributed over the period of operation. A 10-year depreciation period has been assumed and the investment costs thus have been divided by 10.

Furthermore, an assumption of 10% of the total investment costs was made for the annual costs for maintenance and the annual operating costs.

For Germany the amount stated is lower than originally planned because some sub-measures are delayed and will only be finalised after the end of NEXT-ITS 2 and thus show their benefits consequently also only after the finalisation of NEXT-ITS 2. Furthermore, one project (Network control system) mainly in Schleswig-Holstein was carried out under the management of Hamburg which is not a NEXT-ITS Partner. Thus, the related costs (and benefits) also are not stated here. Although it can be expected that it will show similar benefits as the ones stated for measure 5, Network Control (see below). The Norwegian costs of 40 000 Euros have not been part of the application (because the Norwegian projects are not funded by EC), but have been stated here, because also the benefits have been taken into account.

The table below provides a summary of the planned project costs which are related to the benefits stated in this report.

Costs NEXT-ITS 2 Euros (2017 prices)	Planned investm. Costs	Investment annual basis	Annual costs oper./maint.	Total annual costs
Denmark	5 570 000	557 000	557 000	1 114 000
Finland	6 200 000	620 000	620 000	1 240 000
Germany	5 511 000	551 100	551 100	1 102 200
Norway	40 000	4 000	4 000	8 000
Sweden	10 400 000	1 040 000	1 040 000	2 080 000
Total	**27 721 000**	**2 772 100**	**2 772 100**	**5 544 200**

Table 4 - The total annual costs of NEXT-ITS 2 services shown per country (excl. interest rate)

As a result, total annual costs of 5 544 200 Euros have been estimated. These costs would fully incur from 2019 when all systems are fully in operation. For the year 2018 the annual costs would be slightly lower because some of the systems will not start exactly on January 1st with full operation (e.g. test phase or fully operation starting End of January, February etc).

For measure 5 (Germany) the calculation of the costs can be shown as an example, because the costs from a detailed ex-ante evaluation (benefit-cost assessments) are available:

- Sub-measure Network control, Hannover-Braunschweig Salzgitter
- Ramp Metering, Schleswig-Holstein

For the **ramp metering system** 0.409 Million Euros as investment costs have been estimated based on the experience from similar systems.

The investment costs are distributed on a 10-year depreciation period with an interest rate of 3%. This results to an annuity factor of 0.11723. Thus, the annual investment costs amount to 47 947 Euros.

As annual costs for operation 3175 Euros have been estimated and 6000 Euros for maintenance.

As results annual costs of 57 122 Euros were estimated.

Ramp Metering system	Total	calculated for one year
Investment cost	409 000	47 947
Maintenance	6 000	6 000
Operating costs	3 175	3 175
Total annual costs		**57 122**

Table 5 - Cost calculation for the ramp metering system in Germany

For the **network control system** 4.036 Mio Euros as investment costs have been estimated. The estimation is based on experience from similar systems.

The investment costs are distributed on a 10-year depreciation period with an interest rate of 3%. This results to an annuity factor of 0.11723. Thus, the annual investment costs amount to 473 140 Euros.

As annual costs for operating and maintenance 8.3% have been estimated. Generally, in Germany for the main investments (i.e. gantries, VMS etc.) 10% are used and for monitoring systems 5%. The network control systems comprise roughly 2/3 main investments and 1/3 monitoring systems, resulting in 8.3% annual costs for operating and maintenance.

As results, annual costs of 684 043 Euros were estimated.

Network control	Total	calculated for one year
Investment cost	4 036 000	473 140
Oper./Maint. costs		210 903
Total annual costs		**684 043**

Table 6 - Cost calculation for the Network Control system in Germany

5.3 Benefits

When transferring the benefits into monetary values, the national unit values of each country were used. As one can see (table 7), the values vary a lot depending on the country, and hence it is important to use these national ones to allow the national authorities to see the benefits of their own deployments.

Values in EURO	**DK**	**NO**	**SE**	**FI**	**DE**
Time values, EUR per vehicle hours:					
Travel time (passenger transport)	21,3	28,8	20,8	12,9	8,4
Delay time (passenger transport)	32,0	N/A	31,2	N/A	N/A
Travel time (freight transport)	71,0	71,0	27,9	25,8	31,9
Delay time (freight transport)	99,1	N/A	41,9	N/A	N/A
Accident values, EUR per accident:					
Fatality (one fatality)	3.958.769	4.059.489	2.772.158	2.911.116	1.271.410

Non-fatal injury accident	914.789	379.499	511.273	439.892	127.594
Emission values, EUR per ton CO2	10,6	34,0	119,3	40,0	102,8
Vehicle operating costs, EUR per km:					
Light vehicles	0,39	0,20	0,28	0,15	0,40
Heavy vehicles	0,66	0,61	0,78	0,49	0,70

Table 7. National unit values used in NEXT-ITS 2 (Year 2017 and 2017 prices).

In table 7, it should be noted that only Denmark and Sweden do have values for delay time. In relation to fatalities, the value is per fatality instead of per fatal accident. Further, for Germany the value of a non-fatal injury accident is per person and not per accident.

The monetary benefits for each measure and country are calculated by multiplying the impact (e.g. Travel time savings) with the national unit value (in Euros).

It is important to be as realistic as possible in the assessment of how much the deployments have enhanced the effects. If the service did not exist at all before the project - and is now in full effect, then the improvement (effect enhanced) is 100%. In all other cases it is smaller. In NEXT-ITS 2 analyses mostly in the range 1% - 10% (Refer to annexes with explanations per measure).

Finally, the total NEXT-ITS 2 annual benefits are calculated as a sum of the national benefits (corresponding to the sum of the benefits of each measure).

Total annual benefits	**Monetary value in M€ (using national unit values)**					
	DE	**DK**	**FI**	**NO**	**SE**	**Total**
Vehicle hours driven	-1.17	-2.90	-1.05	0.00	-4.10	**-9.22**
Vehicle hours spent in congestion	-0.58	-1.22	-0.09	0.00	-1.34	**-3.23**
Fatalities	-0.01	-0.08	-0.16	-0.01	-0.06	**-0.32**
Injury accidents	-0.02	-0.18	-0.44	-0.02	-0.53	**-1.19**
CO2 emissions	-0.20	-0.03	-0.06	0.00	-0.66	**-0.95**
Total benefits in M€	**-1.98**	**-4.40**	**-1.80**	**-0.03**	**-6.70**	**-14.91**

Table 8. Monetary values of estimated annual benefits of NEXT-ITS 2 measures

It should be noted that vehicle operating costs are not included. Rerouting leads to increased vehicle operating costs and thereby reduction of the total benefits. However, it has been too complicated to try to estimate the extra vehicle kilometers driven due to rerouting.

5.4 Benefit Cost Ratio

As explained in section 5.1 the evaluation is not a full cost benefit analysis and therefore it is not feasible to talk about or calculate a "benefit cost ratio". However, the approach is to compare a number of estimated benefits to the costs of the measures.

The benefits are estimated to **14.9 million Euros per year**. The total costs are estimated to approximately 5.5 million Euros per year, when using a 10-year lifetime.

If looking at the deployment (investment) costs only, these are in total 27.7 million Euros excl. VAT.

When comparing the benefits with the costs, the VAT should be included in the costs which gives a cost estimate of approximately **33.3 million Euros** incl. VAT.

The operation and maintenance costs are estimated to approximately 2.77 million Euros per year excl. VAT and to **3.35 million Euros per year** incl. VAT.

If looking at e.g. 4 years (2018-2021), the total costs amount to 46.7 million Euros and the total benefits to 59.6 million Euros; BUT the costs are without interest rates, Net Tax Factor etc. which will have to be included in a solid (real) socio-economic calculation of the benefit cost ratio.

A rough estimate is therefore, that the NEXT-ITS 2 deployments will be beneficial in about 5 - 6 years.

It should be noted that the rough estimate is based on generally cautious and conservative estimates of the effect enhanced by the services and impact estimates as well.

6 Overall Assessment & Transferability of the Results (European Dimension)

6.1 Overall Assessment

The evaluation is based on a number of measures deployed on the NEXT-ITS 2 corridor and in traffic management centres in order to move from local traffic management towards coordinated and cross-border management of the whole corridor. The evaluation covered the services deployed or enhanced by the road authorities involved during the period 2015-2017, also including some measures completed fully in early 2018. The objective has primarily been to evaluate the costs and impacts of the services deployed i.e. how the measures contribute to reduction in travel time, accidents and emissions from road transport.

The total length of the NEXT-ITS corridor itself is about 3 000 km, but the impacts of the NEXT-ITS 2 measures cover a much larger road network, about 25 000 km. This is due to the fact that many measures focus on improving the effectiveness and quality of traffic centre operations. In the participating countries, the traffic management centres of the road authorities provide their services on the whole comprehensive TEN-T network, and even wider, on the whole main road network including the arterials to the bigger cities connected by the main road networks.

Hence, in order to cover all benefits of the measures in a fair way, also the contribution of the NEXT-ITS 2 measures to solving transport problems outside the actual corridor have been taken into account. As the contribution of the measures to the effectiveness of existing ITS services varies by measure and type of service, the road network affected by the service had to be separated in several different sub-networks in some countries to be able to estimate the impacts of NEXT-ITS 2 as correctly as possible. In these cases, the impacts were first calculated separately for each sub-network, and then summed up for all networks impacted by NEXT-ITS 2 measures in the countries.

The evaluation was carried out as an ex-ante evaluation, taking the estimated benefits of the measures into account. The expected impacts of the deployed services on the NEXT-ITS 2 corridor are based on experience from the impact assessment studies available for the traffic management and information services deployed and enhanced via the measures implemented in 2015-2017. While taking into account the results from existing studies, especially from regions outside NEXT-ITS, the results were adapted somewhat in order to consider the differences in traffic and environmental conditions between the ones in the impact studies and the ones prevailing on the NEXT-ITS 2 networks.

The total estimated effects of the services are considerable, about 490 000 vehicle hours driven less and circa 135 000 vehicle hours less spent in congestion annually. About three severe accidents and 11 000 tonnes of CO_2 emissions are avoided annually due to NEXT-ITS. The total value of the annual benefits in 2017 will be circa 15 Million €, which can be compared to the implementation costs of circa 33 million € including VAT and thereby comparable to the benefits (the costs without VAT amount to almost 27 Million €). As the annual operation and maintenance costs will be in the order of 3 Million €, the NEXT-ITS 2 can be assessed to be socio-economically profitable.

The sensitivity analysis shows that the benefits calculated vary a lot dependant on the most important input parameters. However, it can be concluded that even with conservative estimates, NEXT-ITS 2 has a positive net impact.

It needs to be pointed out that the effect estimates are based on a desk-top analysis, which needs to be compared to the actual statistics from the NEXT-ITS 2 corridor and the national networks affected. Such an ex-post evaluation should be carried out when the services are fully deployed and in use, for instance in 2019. However, it is clear that the effects of the services are extremely difficult to measure especially in the era of technology disruption due to connected and automated driving, the internet of things, digitalisation, etc. Thereby, even the ex-post evaluation needs to be accompanied with a desk-top analysis similar to the ex-ante assessment reported here.

6.1.1 Deployment

Generally, the deployments have been carried out as planned and most systems are in operation at the end of 2017. For a few systems full operation will start in the first quarter of 2018 although the deployments have been finalised because some adaptions or test phases are necessary before the full operation.

Two sub-measures on Network Control in Germany (Measure 5) were planned to be carried out during NEXT-ITS 2, but were delayed respectively could not be taken into account. Both are network control systems with a similar effect on the same services as the Network control system carried out in Germany (Measure 5, Network Control Hannover-Braunschweig-Salzgitter):

- **Network Control System/Traffic Management Plan A1/A7/A21/B205**: This system is being carried out according to plan. However, it cannot be stated as NEXT-ITS 2 project because the coordination and management is carried out by Hamburg which is not a NEXT-ITS 2 partner. Therefore, both costs and potential benefits have not been taken into account in this analysis.

- **Traffic Management Plan Long Distance Corridor (LDC) North**. This system addresses re-routing in Northern Germany. However, the implementation is delayed and thus will be carried out after the finalisation of NEXT-ITS 2.

For measure 6 also some delays occurred. However mainly related to optimisation, improvement of efficiency or preparations for future enhancements, which cannot be measured in the respect of the key performance indicators.

6.1.2 Safety

The measures and services deployed in NEXT-ITS 2 were mainly focusing on network management and incident management, and hence improving traffic flow. The benefits on safety were somewhat smaller than with the NEXT-ITS 1 measures.

However, the services that are part of the measures are still under deployment during the NEXT-ITS 3, and with the full integration of all the planned services into the central TMC systems, such as T-LOIK in Finland among others, the safety benefits will increase, too.

6.1.3 Efficiency

The major part of the benefits in NEXT-ITS 2 results from gains in travel times, both in congestion and in uncongested flow. This is mainly due to the NEXT-ITS 2 focus in enhancing corridor management, and in many cases enhancing especially incident management, including incident warnings and traffic management plans. Also, local traffic management deployments contributed to increased efficiency.

It is also the case that with the existing unit values used for socio-economic calculations in transport, accompanied with the considerable improvement of road safety in northern Europe during the past decades, travel time delays form today the clearly largest part of the external costs caused by transport on the NEXT-ITS 2 network.

As mentioned in section 5.3, it should be noted that the increased vehicle operating costs due to rerouting are not included and would reduce the total benefits.

6.1.4 Environment

The measures in NEXT-ITS 2 are mainly focused on the motorway road network between cities. How the measures influence CO_2 emissions are included in the benefit calculation. The impact on local air pollution, like NO_X, is therefore not included in the calculations, because this is mainly an issue in urban areas and cities, and has not been taken into account in NEXT-ITS 2.

6.2 Transferability of results (European Dimension)

The deployment context, impacts, benefits and costs of a specific ITS service depend strongly in the local, regional and national conditions. The main factor for traffic management and information service evaluation results transferability is the corridor traffic status, including the major transport problems experienced on the corridor.

NEXT-ITS 2 corridor and the road networks affected by NEXT-ITS 2 measures differ from the core and comprehensive networks in central Europe in the following ways:

- Much less congestion, and shorter durations of congestion
- Weather, and especially winter weather is a much more important source of transport problems in the Northern parts of Europe than elsewhere in Europe
- Road safety is at a somewhat higher level
- The share of incidents as a cause for congestion is higher and the share of over-demand respectively lower

For these reasons, the impacts of traffic management and information in NEXT-ITS 2 tend to be lower than they would be in central Europe on travel times, especially outside congestions whereas the impacts of weather information tend to be higher.

Hence, the results are not applicable as such to the rest of Europe. Nevertheless, the directions of the impacts of the measures are certainly transferable even though the magnitudes would not be. Furthermore, it is also very likely that traffic centre level measures to integrate operations towards coordinated corridor management will enhance the performance of individual or local traffic management and information services also elsewhere than in the NEXT-ITS region.

The element most easily transferable is the evaluation methodology with the transparent impact table and calculation mechanisms.

6.2.1 Relevance to ITS Priority Areas and Actions

The NEXT-ITS 2 action is mostly related to the EU ITS Action Plan's [European Commission 2008) action area 2: Continuity of traffic and freight management ITS services on European transport corridors and in conurbations, with links to areas 1: Optimal use of road, traffic and travel data, and 4: Integration of the vehicle into the transport infrastructure.

The main relevance for area 2 is illustrating the benefits from continuity of services in the form of coordinated corridor management by filling local gaps in traffic management and especially integrating traffic management centre operations to enable corridor management in daily operations.

For area 1, the main relevance is showing the benefits of corridor management to the enhancement of traffic information services, and especially multimodal, real-time and safety-related information services i.e. those specified in the European Commission's ITS Directive's delegated acts for priority actions a), b) and c), respectively (European Commission 2010, 2017a, 2015, 2013)

For area 4, the results will be more in the future. Coordinated corridor management resulting in a shared transport system situational picture, traffic management and incident management plans are essential to the fleets of connected and automated vehicles. In this respect the results support fully the work and conclusions of the Enhanced traffic management working group in the C-ITS Platform's II Phase (European Commission 2017b).

7 References

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Annexes

8 Measure 1 – TMC renewal and adaptation to corridor management and control systems, FI

8.1 Measure descriptions; how NEXT-ITS 2 measures have improved the services

To ensure corridor-oriented strategic traffic management, all existing traffic management and control systems will be adapted to the Traffic Management Centre (TMC) operator support and control systems, and integrated with the control room facilities at the TMC. In practice, this means the renewal of control room software, control logic software, and control equipment. In addition, TMC equipment is purchased to facilitate use of the T-LOIK operator support system, and the CCTV control system is renewed. The adaptation covers traffic management and control systems in the tunnels along the corridor as well as the dynamic traffic management systems (dynamic speed limits accompanied with incident, congestion and/or weather warnings) on 20 km of the corridor.

The current traffic management system as a whole is a dedicated, very complex operational control system entity, consisting of a number of systems and subsystems operated on a high availability platform, which enables the exchange of information and co-operation between authorities. There are about 50 Individual road sections or individual traffic management systems that are controlled with about 40 different management systems or interfaces. The current traffic management systems have been developed between the years 1987-2014. Technical details differ significantly due the vast span of development, even though some of higher-level harmonization efforts have been made in recent years. Infrastructure investment projects (e.g. tunnels, new roads) annually produce 2-5 new traffic control systems to the "system family".

The selected Finnish measure will produce an integrated traffic management system and user interface which will significantly renew traffic management centre operations. The integrated user interface is called T-LOIK, and will be the main operational tool for traffic management centres used for situational awareness and traffic management. T- LOIK will plan and implement a uniform integrated user interface as well as a technical integration platform, which will integrate local traffic management systems in a consistent manner. It will enable a cost-effective life-cycle management of traffic management systems and roadside technologies as well as enable the development of new business services in an easy and cost-effective manner and introduce a uniform way to develop traffic management and information. In addition, T-LOIK will enable the harmonisation of work done by duty-officers and make a more efficient use of human resources possible. The whole Finnish part of the NEXT-ITS 2 corridor will be dealt with by the measure, and its focus will be on the most critical sections. The integration action covers in NEXT-ITS 2 the following tunnels and sections:

Tunnels

- Ring II urban link Hiidenkallio tunnel, Espoo — Slight delay, to be completed by April 2018
- Ring III urban link Vuosaari tunnel, Helsinki — Completed
- Highway 1 (E18) Turku-Muurla, Isokylä tunnel — Completed

New ones:

- Highway 7 E18 Rasa-Ahomäki tunnel — Started, to be completed by April 2018

Sections and border crossings, excluding tunnels

- Highway 1(E18) Ring III – Lohja — Partly completed, fully by April 2018

- Highway 50 (E18, Ring III) Completed
- Highway 7 (E18) Vaalimaa border crossing Slight delay, to be completed by April 2018

New ones, except from application:

- Highway 1 (E18) Turku – Muurla Completed
- Highway 7 (E18) Ring III - Porvoo Completed
- Highway 7 (E18) Hamina-Vaalimaa Started, to be completed by April 2018
- Highway 51 Länsiväylä Completed

Service impacts in NEXT-ITS 2 (effect enhanced) are listed in the following table:

Measure 1	Forecast and real-time event Infor-mation Service	Traffic Condition and Travel Time Infor-mation Service	Weather Information Service	Safety Related Traffic Infor-mation Service	Dynamic Lane Management	Variable Speed Limits	Incident Warning and Manage-ment	Ramp Metering	Traffic Management Plans for Corridors and Networks
TMC renewal and adaptation to corridor management and control systems, FI	2 %	-	1 %	-	1 %	10 %	10 %	-	1 - 2.5%

Finnish Measure 1 has enhanced or affected services in the following way:

- Forecast and real-time event Information Service
    - The integration of roadside unit control systems has had the following positive impacts:
        - less latency
        - systems are better synchronized, no more system-specific interfaces (for operators/road users – technical solutions covering many interfaces)
        - Most benefits have been already included into NEXT-ITS 1 benefit calculations, and hence only 2% additional impacts have been estimated to be a result of NEXT-ITS 2 deployments.

- Weather Information Service
    - The integration of roadside unit control systems has had the following positive impacts:
        - less latency
        - Most benefits have been taken into account in NEXT-ITS 1, hence only 1% additional impacts have been estimated to be a result of NEXT-ITS 2 deployments.

- Dynamic lane management
    - Only the user interface has been transferred from the preceding Scada systems to T-LOIK, no functional improvements were made yet during NEXT-ITS 2 period.
    - The increase in service benefits was estimated to be very low, only 1%.

- Variable speed limits
    - The integration of variable speed limit systems allows more flexible use
    - less latency
    - Referring to the above, the increase in service benefits was estimated to be 10%.

- Incident warning and management
    - The integration of the roadside information and warning systems allows more flexible use and more effective technical interoperability.

8.2 The relation to NEXT-ITS1 (and if to continue in NEXT-ITS3)

The integration layer of T-LOIK system focuses on developing a wide scale integration of traffic control systems, GIS and on road data collection. Furthermore the integration layer also includes software services for analysing and breeding data into intelligent information to be utilized by traffic management, road users and service providers. With this modular multi-layer software architecture it is possible to utilize existing and new information and data collection sources (especially incident information as well as floating cellular/vehicle data on road surface condition and travel time) to it, increasing the use of existing VMS for warnings and information, and in general making the traffic information service process much more efficient and increasing its quality.

The new T-LOIK system has shared in three main development phases. The first phase concern the base system and test integrations. The first phase was completed by the end of 2014 and has been part of NEXT-ITS 1.

The second phase will be the first complete operational entity covering the NEXT-ITS corridor, and will be completed by the end of 2017.The second phase is included to the NEXT-ITS 2.

The last, i.e. third phase, will complete all integrations and features, and will be implemented by 2020 as a part of NEXT ITS 3. e.g. the following integrations will be completed in NEXT-ITS3:

- Ring I Mestari tunnel, Espoo -> Delay, to be completed by end 2018
- E18 urban link Hakamäentie tunnel, Helsinki -> Delay, to be completed by end 2018
- E18 Muurla-Lohja tunnels seven tunnels -> (tbd: outside FTA jurisdiction)

8.3 Network(s) affected by the measure, Network description & Network statistics - and assumptions behind the calculations, data sources

In the application, it was expected that the Finnish measure will facilitate strategic traffic management utilizing the already existing traffic management systems along the corridor, and thereby improve safety, efficiency, environment and mobility of people and goods along the corridor especially via corridor oriented efficient traffic and incident management.

In the current benefit calculations, the total network impacted by NEXT-ITS 2 Finnish measure has been divided into five network classes according to the level of service deployed or improved during NEXT-ITS 2. Network 1 includes all of the services, which were part of FI NEXT-ITS 2 measure and Network 5 only one of the services, namely weather information. The network classification was based on the level of service in each road section.

The network statistic values are based on general valid national statistics, such as the accident and road registers. Table 1 summarizes the network statistics of all FI networks in NEXT-ITS 2.

Table 1. Network statistics in FI networks included in NEXT-ITS 2 benefit calculations.

TOTAL NETWORK	2016	2017 estimated
Length (km)	13703.1	13703.1
Vehicle kilometres driven (million/year)	26917.0	27993.7
Vehicle hours driven (million/year)	336.5	349.9
Vehicle hours spend in congestion (M/year)	0.57	0.59
Fatal accidents (number/year)	174.0	172.8
Non-fatal injury accidents (number/year)	2405.3	2439.0
Co2 emissions (million tonnes/year)	6.8	7.1

Length (km) has been collected for each network from Tierekisteri (road register) one road at a time, with the updates from 2016. The Network at 2017 has been set to be the same as 2016.

Vehicle kilometers driven (million/year) have also been calculated as a summary of vehicle kilometers driven in each road section included in the NEXT-ITS 2. Tierkisteri (road register) includes length of each road section as well as average daily traffic (ATD) (from LAMs), and hence the vehicle kilometers driven can be calculated as with the formula ADT*length*365. Official statistics for ADT and hence vehicle kilometers driven was available for 2015 and 2016, and the 2017 was extrapolated with the linear increase in traffic (the same annual increase expected than in NEXT-ITS1/most advanced network, i.e. 4%).

Vehicle hours driven (million/year), was calculated from vehicle kilometers driven, with the average speed of 80 km/h (most common speed limit on Finnish main public roads).

Vehicle hours spend in congestion (M/year), When estimating the vehicle hours spent in congestion, the earlier studies of the delays were used (referred in the proposal) – and assuming 2% vehicle our driven to be in congestion for networks 2 and 3. No congestion was estimated for networks 1, 4 or 5.

Fatal accidents (number/year), were collected from national accident database (TIIRA). For fatal accident calculations the real accident numbers for 2014, 2015 and 2016 were used as a basis, and the 2017 numbers were calculated from that data with the following assumption: fatal accident rate -4.5% year (according to Elvik et. al. 2015). Note that for the shorter networks the average of three years was used to reduce the impact of random variability. For the longest network, a single year data, i.e. 2016 data was used.

Non-fatal injury accidents (number/year), were also collected from national accident database (TIIRA). For injury accident calculations the real accident numbers for 2014, 2015 and 2016 were used as a basis, and the 2017 numbers were calculated from that data with the following assumption: non-fatal injury accident rate -2.5% year (according to Elvik et. al. 2015). Note that for the shorter networks the average of three years was used to reduce the impact of random variability. For the longest network, a single year data, i.e. 2016 data was used.

CO^2 emissions (million tonnes/year), have been calculated with the help of annual kilometers driven and average $C0^2$ emission per vehicle km. In Finland, the 2017 value was based of the values from LIPASTO-tool 259.5g/km (2012) and 254.4g/km (2015), and extrapolated with help of those extrapolated from these 252 g/km for 2017.

Databases used for the road and accident statistics are TIIRA (accidents) and Tierekisteri (Road register; for road network statistics), both owned and maintained by Finnish Transport Agency. All statistics (injuries, fatalities, length of the corridor and vehicle kilometers driven are calculated by combining the TIIRA and respectively Road register -data road section by road section. The data does not include any alternative/near-by roads, but only the sections in the selected corridors. Road register includes the information on the numbers of vehicles in each section, length of each section, and TIIRA the number of fatalities and injuries in each section

In addition, for the largest network, i.e. all main roads – the data was collected from the official Finnish road statistics publication (Liikennevirasto, 2016), which includes the length of the road network, the vehicle kilometers driven in each part of the network, as well as accident statistics for fatal and non-fatal injury accidents. . For the largest network, the one-year accident data (2016) was used due to length of the network and hence much smaller random variation than for the shorter networks (where the 3-year data was used as explained above).

All networks consist of TEN-T roads (core and comprehensive), except networks 4 and 5, that also include sections of public main roads.

Network 1:

NETWORK 1	***2016***	***2017 estimated***
Lenght (km)	4.1	4.1
Vehicle kilometers driven (million/year)	12.3	*12.8*
Vehicle hours driven (million/year)	0.2	*0.2*
Vehicle hours spend in congestion (M/year)	0.0	0.0
Fatal accidents (number/year)	0.0	*0.0*
Non-fatal injury accidents (number/year)	0.3	*0.3*
Co2 emissions (million tonnes/year)	*0.0030895*	*0.0032131*

The network includes the following services: Forecast and real time event info, Weather information service, Dynamic lane management, Variable speed limits, Incident warning and management, Traffic management plans

Network 2:

NETWORK 2	2016	2017 estimated
Lenght (km)	177.1	177.1
Vehicle kilometres driven (million/year)	1321.8	*1374.7*
Vehicle hours driven (million/year)	16.2	*16.9*
Vehicle hours spend in congestion (M/year)	0.3	0.34
Fatal accidents (number/year)	0.3	*0.3*
Non-fatal injury accidents (number/year)	26.0	*26.4*
Co2 emissions (million tonnes/year)	*0.3331060*	*0.3464302*

The network includes the following services: Forecast and real time event info, Traffic condition and travel time info, Weather information service, Variable speed limits, Incident warning and management, Traffic management plans

Network 3:

NETWORK 3	2016	2017 estimated
Lenght (km)	56.9	56.9
Vehicle kilometres driven (million/year)	955.9	*994.1*
Vehicle hours driven (million/year)	11.7	*12.2*
Vehicle hours spend in congestion (M/year)	0.2	0.24
Fatal accidents (number/year)	0.7	*0.7*
Non-fatal injury accidents (number/year)	21.0	*21.3*
Co2 emissions (million tonnes/year)	*0.2408788*	*0.2505139*

The network includes the following services: Real time event information, Weather information, Incident warning, Traffic management plan

Network 4:

NETWORK 4	2016	2017 estimated
Lenght (km)	4399.6	4399.6
Vehicle kilometres driven (million/year)	16541.6	*17203.2*
Vehicle hours driven (million/year)	206.8	*215.0*
Vehicle hours spend in congestion (M/year)	0.0	0.00
Fatal accidents (number/year)	56.0	*55.6*

Non-fatal injury accidents (number/year)	567.0	*574.9*
Co2 emissions (million tonnes/year)	*4.16847*	*4.33521*

The network includes the following services: Weather information, traffic management plans

Network 5:

NETWORK 5	***2016***	***2017 estimated***
Lenght (km)	9065.4	9065.4
Vehicle kilometres driven (million/year)	8085.4	*8408.9*
Vehicle hours driven (million/year)	101.1	*105.1*
Vehicle hours spend in congestion (M/year)	0.0	0.00
Fatal accidents (number/year)	117.0	*116.2*
Non-fatal injury accidents (number/year)	1791.0	*1816.1*
Co2 emissions (million tonnes/year)	*2.0375*	*2.1190*

The network includes the following services: weather information service.

8.4 Deployment KPIs + status of the deployments

Since many of NEXT-ITS deployments are in nature such that the area/network they impact is much greater than the NEXT-ITS corridor, it would not be fair to include all the deployment costs in the analysis for the corridor only. Hence, for the benefit estimations and further cost-benefit considerations the network was separately selected based on the nature and real coverage of the service. In addition, for the benefit calculations, the real usage of the service was estimated based on the available user statistics.

Status of the deployment (the rate of T-LOIK integration) - with the logic "how large part of the potential network including the service has been integrated into T-LOIK during NEXT-ITS 2"

Finnish Comprehensive Ten-T Road network + few essential part of the main roads (Networks 1-4) 4637,7 km	**End of 2014** Length km	**End of 2017** Length km	**End of 2014** %	**End of 2017** %
Road weather monitoring[1]	4637.7	4637.7	100	100
Fixed real-time traffic monitoring[2]	4637.7	4637.7	100	100
Mobile/probe real-time traffic monitoring[3]	0	0	0	0
Forecast and real-time event Information[4]	0	238.1	0	31
Traffic Condition and Travel Time Information	0	0	0	0
Weather Information[1]	4637.7	4637.7	100	100
Safety Related Traffic Information[5]	0	0	0	0
Dynamic Lane Management	0	4.1	0	39
Variable Speed Limits	0	181.2	0	30
Incident Warning and Management[4]	0	238.1	0	31
Ramp Metering	-	-	-	-
Traffic Management Plans for Corridors and Networks (e-rerouting available in PoP ely, part of network4)	0	524	0	12

[1]) Also implemented on network 5, but not included in calculation or the table.

[2]) Based on automatic traffic counting (LAM) stations.

[3]) Up to now not implemented in Finland

[4]) Includes only information via VMS.

[5]) Up to now not implemented in Finland

8.5 Technical performance of the systems in operation; How the goals were reached by the deployments

The Finnish measure (Measure 1 in work programme) aims to eliminate the current problems in traffic information services as well as traffic management services. It focuses on improving the quality of traffic information services by developing a common user interface and an integration layer named T-LOIK.

The common interface will support Traffic Centre operators in their daily tasks at informing road users on relevant developments in traffic and managing traffic. The emphases is on developing a usable, all inclusive interface highlighting ease of use and good tools for fast delivery of traffic management actions and information to road users via VMS and other channels of information such as the internet, social media and radio stations. The user interface comprises a map interface, VMS information tool (also for other information channels), alarm tool and road weather display integration.

The integration of T-LOIK enables interoperability of different traffic management systems. Uniform technical control algorithms can be used between different systems, for example for disruption information, whereby flow of traffic will significantly improve.

8.6 References

Liikennevirasto, 2017. Tietilasto/Finnish Road statistics 2016. Liikenneviraston tilastoja 4/2017. Verkkojulkaisu pdf (www.liikennevirasto.fi), ISBN 978-952-317-413-9

9 Measure 2 – Motorway Control System, Sweden

9.1 Measure descriptions; how NEXT-ITS 2 measures have improved the services

Due to the high demand on the existing roads in Sweden's 2 largest cities, Stockholm on the east coast and Gothenburg on the west coast, and the fact that both towns are surrounded by water which makes it hard to build new roads in the area we have to make the most use of existing infrastructure as possible. In some areas we are even forced to take away the hard shoulder and make it into a normal lane which then makes this area especially sensitive for traffic disturbance.

A way of preventing disturbances is to implement modern ITS technology where such is possible and the following systems are planned to be deployed in the major urban nodes (and their urban/interurban interface) to enhance traffic management for road operator and traffic environment for the end user.

1. Motorway Control System in Gothenburg

Reinvestment of Motorway Control System at E6 in Gothenburg between intersections Kallebäck and Åbro and upgrading to MTM-2. Length 5 km. Extent of deployment is:

- 67 fully graphical lane signals including variable speed signs
- 72 microwave detectors for speed and simple classification/counting.
- 19 fully graphical variable warnings signs

The motorway control system (which is historically based on the dutch MTM standard) is based on a new development for a new and more open control system based on the specification from Swedish Transport Administration (STA). This is due the fact that the signs are so advanced and the old control system isn't supporting the possibilities that a fully graphical LED sign has. Implementation expected during 2016.

2. Motorway Control System on E4 and E18 in Stockholm

Reinvestment of Motorway control system and stop detection radar on E4 in Stockholm Northern Link (Haga Norra- Haga Södra, and new investment on E18 (Universitetet-Bergshamra)

Estimated quantities:

- 150 fully graphical lane signals including variable speed signs
- 155 microwave detectors for speed and simple classification/counting.
- 20 fully graphical variable warnings signs
- Full incident coverage by additional Stop detection radars

3. Replacement of VDS on E4 in Stockholm

Replacement of 6 pcs of VDS (variable direction signs) based on prisma technique to LED to reduce the need of maintenance on main highway E4 in Stockholm (Haga Södra)

Replacement of 80 pcs of VDS from prisma signs to full graphical LED signs to display additional traffic symbols.in Stockholm (Southern Link)

<u>Budget (k€)</u>[1]

[1] Support will be requested on the total, not for each measure

Year (end of)	2015	2016	2017	Total
Works total	3 900	1 500	500	5 900

Service impacts in NEXT-ITS 2 (effect enhanced) are listed in the following table:

Measure 2	Forecast and real-time event Infor-mation Service	Traffic Condition and Travel Time Infor-mation Service	Weath er Inform ation Service	Safety Related Traffic Infor-mation Service	Dynamic Lane Manage ment	Variable Speed Limits	Incident Warning and Manage-ment	Ramp Metering	Traffic Management Plans for Corridors and Networks
Motorway Control System, SE	2%	60%	-	3%	15%	-	20%	-	10%

Measure 2 is estimated to enhance affected services in the following way

1) Forecast and Real-time Event Information Service

Providing forecasted and real-time event information and warnings to the road user increases the safety and the efficiency of the network. Being informed about traffic problems the drivers are prepared for an incident or congestion and can react accordingly thus improving the safety. Re-routing information contributes also to a better use of the network in which congestion will be reduced.

An effect of 2% has been estimated.

2) Traffic Condition and Travel Time Information Service

Real-time and on-trip travel condition information will allow the road users to adapt their driving behaviour according to the traffic conditions. Information related to traffic conditions, incidents and accidents and stated possible re-routing advice allows changing the route leading to the network being used in a more efficient way.

An effect of 60% has been estimated.

3) Safety Related Traffic Information Service

Real-time traffic information contributes to meeting the objective of improving safety as well as the efficiency of the network by preparing the end user, before and during the journey, for expected as well as unexpected events. This will allow them to adapt their travelling behavior (e.g. rerouting, choosing alternative modes of transportation, change of time for travel and adaptation of driving behavior – speed, distance to vehicle ahead etc.). On- and pre-trip information about traffic conditions, expected travel times and the weather are provided through a range of media, including internet portals, television and mobile devices/PDAs (pre-trip) as well as variable message signs, navigation systems or the radio (on-trip).

An effect of 3% has been estimated.

4) Dynamic Lane Management

Dynamic lane management (DLM) service enables a temporally modifiable allocation of lanes by means of traffic guidance panels, permanent light signals, multiple-faced signs, LED road markers, closing and directing installations, etc. The service has a potential to enhance traffic fluidity of the network.

An effect of 15% has been estimated.

5) Incident Warning and Management

Incident management involves the implementation of a systematic, planned and coordinated set of responsive actions and resources to prevent accidents in potentially dangerous situations and to handle incidents safely and quickly. It proceeds through a cycle of several phases: from incident detection to restoration of normal traffic conditions, including the use of immediate and advance notice of possible dangers or problems, i.e. warnings, in order to prevent accidents. It is expected that the Swedish measure will enhance the capability for timely notification via new MCS components.

An effect of 20% has been estimated.

6) Traffic Management Plans for Corridors and Networks

Traffic Management Plan for Corridors and Networks (TMP) involves a pre-defined allocation of a set of measures to a specific situation to control and guide traffic flows as well as to inform road-users in real-time and provide a consistent and timely service to the road user. Initial situations can be unforeseeable (incidents, accidents) or predictable (recurrent or non-recurrent events). The measures are always applied on a temporary basis.

An effect of 10% has been estimated.

9.2 Explain the relation to NEXT-ITS1 (and if to continue in NEXT-ITS3)

The reinvestment and implementation of new components of the MCS has been carried out during NEXT-ITS 2. Many of the measures are part of NEXT-ITS 1 which were carried out before the start of NEXT-ITS 2.

During NEXT-ITS 3 implementations will be put in place for expanding capabilities for Variable Speed Limit will be carried out.

9.3 Network affected by the measure, Network description & Network statistics - and assumptions behind the calculations, data sources

The network consists of motorways affected by the measure.

NETWORK	*2014*	*2017 estimated*
Lenght (km)	1874.5	1874.5
Vehicle kilometers driven (million/year)	11732.4	12413.8
Vehicle hours driven (million/year)	131.9	139.6
Vehicle hours spend in congestion (M/year)	6.6	7.0
Fatal accidents (number/year)	9.0	8.8

Non-fatal injury accidents (number/year)	451.0	440.8
Co2 emissions (million tonnes/year)	3.7	3.9

Length (km) has been calculated for the roads influenced by

- 67 fully graphical lane signals including variable speed signs
- 72 microwave detectors for speed and simple classification/counting.
- 19 fully graphical variable warnings signs
- 150 fully graphical lane signals including variable speed signs
- 155 microwave detectors for speed and simple classification/counting.
- 20 fully graphical variable warnings signs
- Full incident coverage by additional Stop detection radars
- Replacement of 6 pcs of VDS (variable direction signs) based on prisma technique to LED

Vehicle kilometres driven (million/year) have been extrapolated for 2017 from Swedish Transport Administration data calculated linear with traffic increase per road type 1% per year for cars and 1.4% per year in state network for trucks and 1.7% per year for trucks on E-roads.

Vehicle hours driven (million/year) have been calculated from the Swedish Transport Administration's tool for transport prognoses for 2014 and calculated with 95 km/h in corridor for person cars and 80 km/h for trucks and cars in state network, which assumes 88 km/h in total Vehicle hours spend in congestion (M/year).

It was assumed that 12% of all vehicle hours are spent in congestion. 3% is assumed spent in congestion in corridor and 1.5% in state network.

Fatal accidents (number/year): The number of fatal accidents (incidents) are -2.6% year; injuries assumed to be the same (Swedish Transport Administration).

Non-fatal injury accidents (number/year). The number of incidents is stated and not the number of injured.

CO^2 emissions (million tonnes/year): CO^2 emissions are based on number of vehicle kilometers driven multiplied with an emission factor, which is 254 gr/km for private cars and 874 gr/km for heavy vehicles. The figures have been extrapolated for 2017.

The network includes the following services:

Forecast and real-time event info, Traffic Condition and Travel Time Information Service, Safety Related Traffic Information Service, Dynamic lane management, Incident warning and management, Traffic Management Plans Service for Corridors and Networks.

9.4 Deployment KPIs

The NEXT-ITS 2 should provide deployment KPIs for the start of the project (January 2015/End of 2014) until the end of the project (End of 2017).

Recently (October 2017) a national ITS report in relation to the ITS Directive (2010/40/EU) provided some deployment KPIs in the report *“Directive 2010/40/EU Progress Report 2017 Sweden”.*

Deployment KPIs

Swedish Comprehensive Ten-T Road network 6 391 km.	**End of 2014** Length km	**End of 2017** Length km	**End of 2014** %	**End of 2017** %
Road weather monitoring		6 391		
Fixed real-time traffic monitoring		558		
Mobile/probe real-time traffic monitoring		558		
Forecast and real-time event Information		6 391		
Traffic Condition and Travel Time Information		6 391		
Safety Related Traffic Information				
Dynamic Lane Management				
Incident Warning and Management				
Traffic Management Plans for Corridors and Networks				

9.5 Status of the deployments

The MCS system is in operation since the last quarter year of 2015 with the implementation of a New motorway control system ion Haga Norra – Haga Södra. The replaced VDS in Stockholm Southern Link is the last implementation in operation since June 2017.

9.6 Technical performance of the systems in operation; How the goals were reached by the deployments

The measure will facilitate continuation of MCS related services and thus ensure improved traffic flow and safety on the road sections. The upgraded and new system in operation and new road stretches equipped with modern technology enables strategic traffic management.

10 Measure 3 – Integrated Traffic Management, Sweden

10.1 Measure descriptions; how NEXT-ITS 2 measures have improved the services

Trafik Stockholm is one of the Swedish Transport Administration's traffic management centres, it collects, processes and provides traffic information all year round. The centre is responsible for the delivery of information about the current traffic situation to the general public free of charge to users via national access points such as radio, internet and also mobile services. The management centre is run jointly in cooperation with Swedish Transport Administration and City of Stockholm since road network cover urban and state roads.

The National Traffic Management System (NTS) is the top system at Trafik Stockholm that serves the traffic operator. NTS is an operational support system assisting traffic managers in the monitoring and management of traffic and to provide traffic situation information. NTS will be extended during 2015-2018 (and the following years) due to development and integration of new sub-systems to NTS.

The extended NTS enable strategic traffic management and continuity of new and existing services with a higher level of quality and functionality. In addition it will improve the operational excellence for the traffic manager and at lower operational costs for the road operator. The more advanced NTS increase decision support at traffic management centres for the benefit of national and cross border travellers and transportation on the corridor with adjacent VIKING countries such as Finland, Germany, Norway and Denmark.

Subactivity 1: Digital infrastructure – New IT platform (ANDA)

Today about 50 different IT systems manage rail and road infrastructure asset data within STA. It is a time consuming and sometimes an impossible task to access and combine road and rail asset data for a coordinated traffic management. A high quality on the geographic and thematic information is a base for making this task conceivable. The IT-platform will facilitate an efficient data exchange, increased content and defined quality including data collection. It will also define, manage and maintain the road network as the master reference network. The infrastructure assets will reference the road network for it's geographical information.

Subactivity 2 New MCS system (Lane Signalling & Monitoring System-Lassy)

Traffic safety is the number one priority for STA. Every day, thousands of vehicles travel through the main roads and the motorways alone are used by about a million citizens every day. It is important to guide all these users to their destination as fast and safe as possible, by providing them necessary information to plan and execute their trip.

The cities of Stockholm and Göteborg applied a lane signalling system since the mid 1990's. Stockholm set up a cooperation agreement with the Dutch road agency Rijkswaterstaat for the maintenance of this lane signalling system. Rijkswaterstaat announced 2014 a cooperation initiative called Charm, in which it aims to replace the traditional lane signalling system MTM-2 by a system called ATMS. As this development is contradictory to STA desired development strategy, STA must now look into future possibilities and realisations of lane signalling, which is now known as the Swedish Lane Signalling & Monitoring System to be operational in 2018.

Measure contribution to the overall objectives for both subactivities

New technology and software will be developed and used such as the use of faster vehicle detection technology with a higher resolution, support for lane allocation logic with new vehicle detection technologies, replacement of the old MTM-2 system in favour of a new system. To summarise the measure is considered to be mature in both organisational and technical perspective.

- Improve the quality and content of traffic management services on the corridor
- Improve strategic traffic management services by the combination of data from several data sources and providing information to the road users on the corridor
- Improve the operational excellence from a road operator/traffic manager perspective.

Expected benefits

- Better use of existing road infrastructure
- Lower operational costs due to the use of new technology
- Establishment of a single access point of access to the infrastructure asset data (not SPA, only internally)
- Replace the systems NVDB (National Road Database) and BIS (rail asset and information data base) with a common IT environment

Budget (k€)[2]

Year (end of)	2015	2016	2017	Total
Works total	**2 500**	**2 000**	**2 000**	**6 500**

Measure 3 is expected to enhance affected services via its subactivity new MCS system (Lane Signalling & Monitoring System-Lassy) in the following way.

The system, a new MCS system, will be integrated in the traffic management centre and the top system NTS. The new Lane Signalling & Monitoring System is intended for increasing road safety by providing information to the road users of unsafe situations ahead of them. It also provides increased safety to road workers and contributes to smooth traffic flow and mitigating environmental impact of the traffic. The system will also support advanced lane signalling functionality in tunnels and the upcoming Förbifart Stockholm project, due for 2024.

[2] Support will be requested on the total, not for each measure

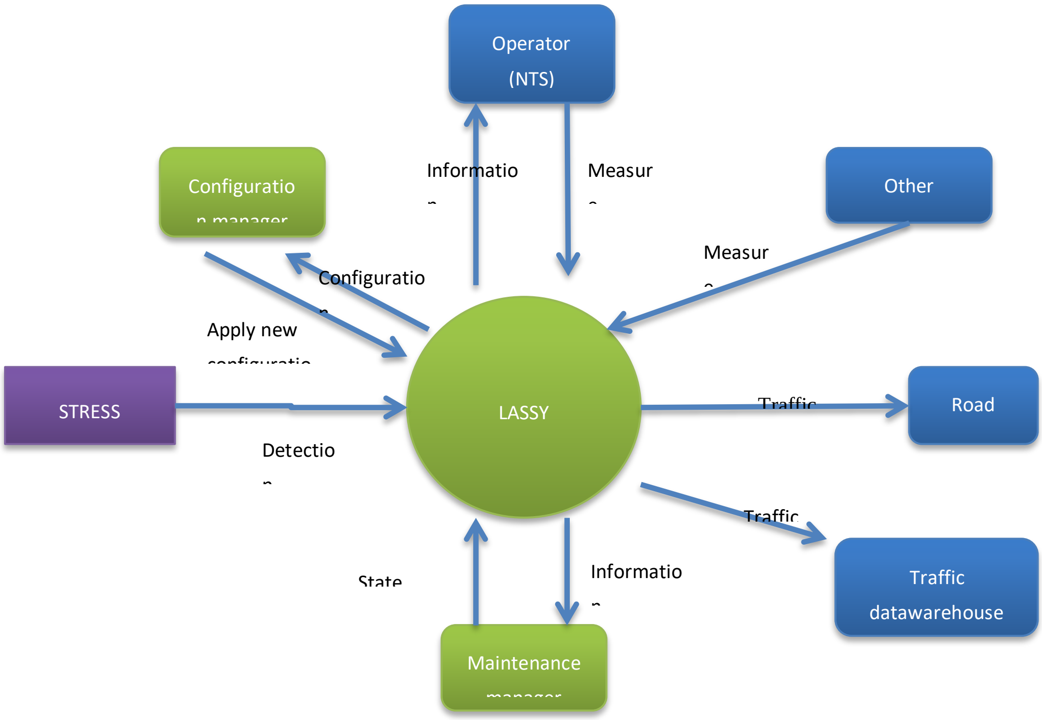

Figure 1: system boundary and environment

The development of the system started with an Operational Concept Design during 2014, system requirement specification and software transition plan ready by November 2015, System development ready by December 2016, test and validation ready by December 2017 and finally implementation start January 2018.

10.2 Explain also the relation to NEXT-ITS1 (and if to continue in NEXT-ITS3)

The implementation of measure 3 and its subactivities has been carried out during NEXT-ITS 2. Preparations (planning etc.) however have been carried out before the start of NEXT-ITS 2.

During NEXT-ITS 3 it is planned substantial work will be carried out in the form of MTLIV which is an extension of ANDA. Ramp metering services are also expected to be enhanced when the New MCS system (Lane Signalling & Monitoring System-Lassy) has been put into place.

10.3 Network affected by the measure, Network description & Network statistics - and assumptions behind the calculations, data sources

The network consists of motorways affected by the New MCS system (Lane Signalling & Monitoring System-Lassy) subactivity.

NETWORK	*2014*	*2017 estimated*
Lenght (km)	1874.5	1874.5
Vehicle kilometers driven (million/year)	11732.4	12413.8
Vehicle hours driven (million/year)	131.9	139.6
Vehicle hours spend in congestion (M/year)	6.6	7.0

Fatal accidents (number/year)	9.0	8.8
Non-fatal injury accidents (number/year)	451.0	440.8
Co2 emissions (million tonnes/year)	3.7	3.9

Vehicle kilometres driven (million/year) have been extrapolated for 2017 from Swedish Transport Administration data calculated linear with traffic increase per road type 1% per year for cars and 1.4% per year in state network for trucks and 1.7% per year for trucks on E-roads.

Vehicle hours driven (million/year) have been calculated from the Swedish Transport Administration's tool for transport prognoses for 2014 and calculated with 95 km/h in corridor for person cars and 80 km/h for trucks and cars in state network, which assumes 88 km/h in total Vehicle hours spend in congestion (M/year).

It was assumed that 12% of all vehicle hours are spent in congestion. 3% is assumed spent in congestion in corridor and 1.5% in state network.

Fatal accidents (number/year): The number of fatal accidents (incidents) are -2.6% year; injuries assumed to be the same (Swedish Transport Administration).

Non-fatal injury accidents (number/year). The number of incidents is stated and not the number of injured.

CO^2 emissions (million tonnes/year): CO^2 emissions are based on number of vehicle kilometers driven multiplied with an emission factor, which is 254 gr/km for private cars and 874 gr/km for heavy vehicles. The figures have been extrapolated for 2017.

The network includes the following services:

Forecast and real-time event info, Traffic Condition and Travel Time Information Service, Safety Related Traffic Information Service, Dynamic lane management, Incident warning and management, Traffic Management Plans Service for Corridors and Networks.

10.4 Deployment KPIs

The NEXT-ITS 2 should provide deployment KPIs for the start of the project (January 2015/End of 2014) until the end of the project (End of 2017).

Recently (October 2017) a national ITS report in relation to the ITS Directive (2010/40/EU) provided some deployment KPIs in the report *"Directive 2010/40/EU Progress Report 2017 Sweden".*

Deployment KPIs

Sweden Comprehensive Ten-T Road network 6 391 km	**End of 2014** Length km	**End of 2017** Length km	**End of 2014** %	**End of 2017** %
Road weather monitoring	6391	6 391	-	100 %
Fixed real-time traffic monitoring	-	558	-	11.5%
Mobile/probe real-time traffic monitoring	-	558	-	11.5%
Forecast and real-time event Information	-	6 391	-	100%

Traffic Condition and Travel Time Information	-	6 391	-	100%
Safety Related Traffic Information	-	-	-	-
Dynamic Lane Management	-	-	-	-
Incident Warning and Management	-	-	-	-
Traffic Management Plans for Corridors and Networks				

10.5 Status of the deployments

Measure started in early 2015.

10.6 Technical performance of the systems in operation; How the goals were reached by the deployments

A continuous and reliable flow of data and information is a crucial prerequisite for an effective infrastructure management. The IT-platform will replace the main national road and rail infrastructure asset data management system, replace the master road and rail network, integrate with other legacy system, create a common information model for infrastructure asset data and establish a single point of access.

11 Measure 4 – New Traffic Management Centre in “The Traffic Tower” in Copenhagen

11.1 Measure description; how NEXT-ITS 2 measure has improved services

1. Measure Description from the Grant Agreement

The measure includes: Deployment of technical installations as well as integration of systems (existing and new) and development of the necessary enhanced cooperation models and partnerships required for performing coordinated traffic management in practice; dedicated efforts in development of traffic operator instructions and plans; implementation of traffic operator education room with training facilities (e.g. off-line simulation); optimization of incident management processes; incident management plan in cooperation with the police and local rescue services.
Furthermore, the measure includes development, test and deployment of a road weather management decision support system, referred to as DIMS. Monitoring of Road State Condition (an import input element to the Decision support system); Upgrade of Road Weather Monitoring Stations where needed.

The measure will improve: Traffic flow and use of existing infrastructure; incident management and handling of emergency situations, with improved traffic safety for all road users as a result; traffic safety due to advanced decision support in road weather management and furthermore a less costly operation in the long term.
The measure will contribute to the NEXT-ITS 2 objectives in three ways: 1) Improve the continuity of traffic management services, in particular at the urban-interurban interface (Copenhagen – Scan-Med motorway by-passing) and on the cross-border sections on the corridor, 2) Improve traffic management services from an end-user perspective by harmonising the services, and 3) Improve the operational excellence from a road operator/traffic manager perspective.

Expected Results:

- Improved traffic flow and better use of existing infrastructure
- Improved incident management and handling of emergency situations, leading to improved traffic safety for all road users
- Improved traffic safety due to advanced decision support in road weather management and a less costly operation in the long term

2. Description of improvements due to the NEXT-ITS 2 deployments

During NEXT-ITS 2, The Danish Road Directorate measure has improved the following service areas:

1) Incident Warning and Management

The measure has included a new incident management plan which is based on evaluations and follow-up meetings with the rescue partners and the police on all motorway incidents that have blocked the motorway in more than two hours. Incident management processes have been optimised at the local level also through a joint effort with the police and various local rescue services. Learning points have been extracted from the evaluations and further processed in a national working group with participation of the police, rescue services and the Danish Road Directorate and finally the result achieved was the new “Manual for Incident Management on motorways” including incident management plans, communication, cooperation, roles and responsibilities among stakeholders etc.

Further, incident detection based on real-time traffic data has been developed and is being tested on a pilot basis in cooperation with the Danish Technological University (DTU).

2) Traffic Information Services (Real-time & Safety related traffic information)

Coverage: The Danish Road Directorate (DRD) acquires real-time traffic data from an external data supplier and has obtained good experiences with the different aspects of the real-time traffic data (acquisition, quality control and use of data). Compared to the situation before, with no acquisition of real-time traffic data from an external supplier, DRD has obtained a far better coverage of the network. (See also section on Deployment KPIs).

Quality and timeliness: According to the ITS Directive Delegated Regulations (c) (SRTI) and (b) (RTTI) the quality of traffic information services must be measured and published. The EC supported projects EIP, EIP+ and EU EIP have all had activities to work out definitions of quality parameters for traffic information, indicate ways to measure these parameters and suggest relevant levels to aim for. An important parameter is “latency”, which is the time from an event is known by the operators in a Traffic Management Centre until it is disseminated (i.e. made available at the National Access Point). This parameter could not easily be monitored in the “old” Traffic Management Centre at DRD, but the new IT-system in the Traffic Management Centre in the Traffic Tower logs data in such a way that the latency can be found.

During the first year of operation of the new IT-system in the Traffic Tower (from October 2015), the monitoring systems were being developed and the latency could be found from generated reports through a manual process. Almost 400 accidents and events/incidents were studied, and the latency in 2016 was found to be within the quality level “**Basic**” part of the time and below this level part of the time. (The quality levels are suggested in the reports from the EIP projects: 95 % of latencies should be below 10 minutes for “Basic” level, and 95 % should be below 5 minutes for “Enhanced” level).

With the possibility to find the latency and to put some focus on it, it was possible to improve it. In 2017, the monitoring systems have been further developed and the latency can be found automatically for most of the incidents. Thus, the latency is found for more than 1000 events/incidents in the first 7 months of 2017. The level has in most of the months been “**Basic**” and in the last two months, it has been within the quality level “**Enhanced**”. Thus, the ability in the new IT-system to monitor quality and the focus put on it by the management of the Traffic management Centre seem to having resulted in an increased quality of the distributed traffic information.

Better dissemination: New ways of improving use of data from drivers via mobile media were tested and user tests conducted; improvements were done to the channels for traffic information (Trafikinfo.dk and Trafikinfo on app) including implementation of push messages.

Further, the Traffic News editorial board within the Danish Broadcasting Corporation (Danish Radio, DR) has moved into the TMC and this has enabled a much closer cooperation resulting in better, faster and more correct traffic information - according to comprehensive user surveys made.

3) Traffic Management Plans for Corridors and Networks

Upgraded facilities in the new TMC: Deployment and technical installations have comprised an IT backbone setup for the Traffic Management Centre, traffic operator work places with four monitors at each desktop and a large video screen wall. These facilities equip the operators with excellent conditions to get overview and thereby provide improved traffic management. Further, the Traffic

Management Centre has established education rooms enabling dedicated education of traffic operators with the possibility to train in an identical system environment.

Enhanced partner cooperation: With the recent technical installations (described above) and additional improvements of important cooperation links with partners like Copenhagen municipality, rescue services, DR (Danish Public Radio), ferry companies and more – the NEXT-ITS 2 has resulted in a much closer cooperation leading to better and faster traffic management – as well for the corridor as for the network.

Further, development and refinement of instructions for the traffic operators have resulted in increased quality of traffic management (according to measurements of operational KPIs, see section 2 below).

The data basis for conducting enhanced traffic management, has also been improved significantly: As of October 2015, the DRD receives real-time traffic data from significant areas of the Danish road network (the appointed strategical road network), as mentioned (above) about coverage.

4) Road Weather Management decision support system

For the Road Weather Management Decision Support system (DIMS), several tests have been accomplished e.g. to determine road sensors ability to detect and measure the road wetness.

In 2017, the Road Weather Management Decision Support are being validated from multiple testing.

VMS based roadside ITS systems – not part of NEXT-ITS 2

There has been a number of permanent larger ITS systems on the Danish Ten-T road network. These systems comprise Motorway Control Systems including traffic information (e.g. travel times). The systems have been operated under a special allocated budget that has run out. Due to the lack of financing, a political decision was made, in the spring of 2017, to turn off these systems temporarily while possibilities of new financing could be investigated - except especially critical systems in relation to tunnels and bridges that have remained in operation. As a consequence, there has been no operational VMS based roadside ITS systems on the Danish TEN-T road network since spring 2017 except in conjunction with bridges and tunnels, and a single system for hard shoulder running on the M13 motorway. Pt. it is uncertain how this situation will evolve.

The consequence of shutting down these systems is that the dissemination of traffic information as well as the dynamic traffic management possibilities (e.g. dynamic lane management and variable speed limits) on the motorway sections in question, are reduced.

3. Operational measure KPIs to indicate effect enhanced by NEXT-ITS 2

The Danish Road Directorate is measuring a range of operational KPIs to follow-up on the performance of the Traffic Management Centre.

The KPI measurements are reported per month and summarized in KPI reports for the management. As an example, latency measurements are shown below in the form of a summary table for measurements of the latency KPI for accident warnings: Time from detection/registration until dissemination.

Uheld - Tid fra indmelding til trafikmelding				
Grøn 93,84 % Gul 83,64 %	Antal stikprøver	Antal sager i alt	Stikprøveandel i procent	Tid fra indmelding til trafikmelding (Max 5 min)
Jan,2017	177	282	62,8%	**86,4%**
Feb,2017	145	241	60,2%	**92,4%**
Mar,2017	217	272	79,8%	**89,4%**
Apr,2017	172	274	62,8%	**93,6%**
Maj,2017	165	240	68,8%	**95,8%**
Jun,2017	166	276	60,1%	**95,8%**
Jul,2017	148	240	61,7%	**93,2%**
Aug,2017	195	292	66,8%	**96,9%**
Sep,2017	232	330	70,3%	**97,4%**
Okt,2017				
Nov,2017				
Dec,2017				
ÅTD	1617	2447	65,9%	**93,4%**

The table shows the percentage of messages where the latency is less than 5 minutes. The latency is the time from detection (/the incident is known by the operators in the TMC) until it is disseminated via traffic information services (and made available at the National Access Point).

Another example is the latency KPI for safety warnings (i.e. incidents influencing traffic safety, like lost goods on the road):

Trafikfarlige hændelser - Tid fra indmelding til trafikmelding				
Grøn 93,84 % Gul 83,64 %	Antal stikprøver	Antal sager i alt	Stikprøveandel i procent	Tid fra indmelding til trafikmelding (Max 5 min)
Jan,2017	722	782	92,3%	**88,5%**
Feb,2017	725	793	91,4%	**89,5%**
Mar,2017	920	988	93,1%	**90,9%**
Apr,2017	900	955	94,2%	**93,9%**
Maj,2017	1249	1331	93,8%	**94,0%**
Jun,2017	1110	1184	93,8%	**94,2%**
Jul,2017	850	895	95,0%	**95,6%**
Aug,2017	1020	1064	95,9%	**95,8%**
Sep,2017	858	887	96,7%	**95,9%**
Okt,2017				
Nov,2017				
Dec,2017				
ÅTD	8354	8879	94,0%	**93,1%**

Again, the table shows the percentage of messages where the latency is less than 5 minutes.

Before and after

The KPI report from September 2017 (latest report available at the time of writing) has been compared with the KPI report from July 2015 to show the improvements in traffic management operations. In total, the KPI report covers 18 operational KPIs for which measurements have been performed.

The KPI report is an internal document and therefore only examples of the KPI measurements have been shown above.

4. Effect enhanced by NEXT-ITS 2

The qualitative descriptions of measure improvements (section 2) and the measured development in operational KPIs (section 3) have led to an assessment of the “Effect enhanced by NEXT-ITS 2”.

The main goals of all the initiatives under NEXT-ITS-2 is to reduce travel time and improve safety on the road network through improved traffic management and incident warning as well as improved traffic information to road users.

During the recent years, the traffic on the Danish motorways has increased significantly and so has the number of incidents. It is therefore not possible to measure the positive effect on travel time or safety due to the NEXT-ITS-2 initiative and separate this positive effect from the negative effect of the significant increase in traffic during the same period. There is however no doubt that the initiatives have had a positive effect on travel time.

As the positive impacts cannot be measured directly on the road network, it is necessary to make an *estimate* of the effect enhanced/improved by NEXT-ITS 2 in order to conduct a rough estimate/calculation of the benefit-cost ratio.

The network covered by e.g. traffic condition information has been extended to a large extent. Deployment KPI shows that in the end of 2014 traffic condition information covered 147 km of the network and in the end of 2017 the entire Comprehensive Ten-T Road network is covered and actually much more than this since the traffic condition information service covers the entire State road network which is 3838 km. I.e. before the traffic condition service covered 4 % of the state road network and now the service covers 100 %.

Traffic Management plans for rerouting in case of large incidents have been made for 38 routes (i.e. 19 routes in two directions) in collaboration with local authorities etc. and signposting of the routes has been established. This has led to much better possibilities of rerouting traffic in case of large and/or long-lasting incidents.

All in all, *the extended coverage of services and the operational improvements due to the upgraded systems and procedures in the new TMC* have resulted in positive impacts compared to the situation before the NEXT-ITS 2 measures were deployed. A rough and very *precautionary estimate* would be that the improvements from before (end of 2014) to after (end of 2017) are *in the range of 1 to 5 %,* where traffic condition information has the highest effect enhanced or additional effect.

Generally, great precaution should be taken due to the nature of the NEXT-ITS 2 deployments for which it is not possible to measure directly the resulting effects on traffic and users and therefore the interval given is the best possible *estimate* and it should be noted that there are many uncertainties in relation to such an estimate.

The Road Weather Management decision support system does naturally result in improved road weather management and actually an improved road weather information service also, but it has been too difficult to assess the improvements in a quantitative manner and therefore the effect enhanced by NEXT-ITS 2 is not included due to a principle of being conservative in the estimates and having a precautionary approach.

11.2 Network(s) affected by the measure, Network description & Network statistics - and assumptions behind the calculations, data sources

The road network affected by the measure is the state road network, i.e. the road network maintained and operated by the national road administration. The state road network is 3838 km. Network statistics are given below.

Services are primarily benefitting **the state road network**	Value 2015*	Value 2017
Length (km)	**3838.0**	**3838.0**
Vehicle kilometres driven (million/year)	**23442.0**	**24379.7**
Vehicle hours driven (million/year)	**268.0**	**281.4**
Vehicle hours spent in congestion (M/year)	**11.90**	**12.61**
Fatalities (number/year)	**52**	**52**
Injury accidents (number/year)	**481.5**	**481.5**
CO_2 emissions (million tonnes/year)	**5.90**	**6.02**

*Accident numbers and fatalities are average of 2015-2016 (Source: “Trafikulykker for året 2016”, Vejdirektoratet); vehicle kilometres and hours are based on official Road Directorate statistics and GPS-data.

Explanation and assumptions behind the network statistics:

Length (km)	network in 2017 is the same as in 2015, except 2 km
Vehicle kilometres driven (million/year)	linear increase, extrapolated from 2015 with 4% in accordance with the Danish national traffic model assumptions
Vehicle hours driven (million/year)	extrapolated with 5 % i.e. extra 1 % due to assumed decrease in average speed due to increase in traffic and congestion
Vehicle hours spent in congestion (M/year)	extrapolated with 5 % i.e. extra 1 % due to assumed decrease in average speed due to increase in traffic and congestion
Fatalities (number/year)	assumption is same number of fatalities; number of fatalities are average of 2015-2016
Injury accidents (number/year)	assumption is same number of accidents due to improvements in traffic safety compensate for increase in traffic; number is average of 2015-2016
CO2 emissions (million tonnes/year)	extrapolated with 2 % i.e. only half of the increase in the vehicle kilometres driven due to more energy efficient vehicles

The network includes the following services:

Traffic condition information, Weather information, Incident warning and management, Traffic management plans for corridors and networks.

(More services exist on the network, but they are not influenced by the project to a significant extent).

11.3 Deployment KPIs

Deployment KPIs is to assess the share of road network covered by data monitoring, traffic management and control etc.

The relevant KPIs will be assessed in order to describe the change from the start to the end of the project.

The NEXT-ITS 2 should provide deployment KPIs for the start of the project (January 2015/End of 2014) until the end of the project (End of 2017).

Recently a national ITS report in relation to the ITS Directive (2010/40/EU) provided some deployment KPIs (for the end of 2016) for the *Danish Comprehensive Ten-T Road network*. Therefore, it has been feasible to use the same network as basis for the status of the relevant Deployment KPIs.

Deployment KPIs

Danish Comprehensive Ten-T Road network 1609 km	**End of 2014** Length km	**End of 2017** Length km
Road weather monitoring	1607	1609
Fixed real-time traffic monitoring	147	147
Mobile/probe real-time traffic monitoring	0	1609
Forecast and real-time event Information	-	-
Traffic Condition and Travel Time Information	147	1609
Weather Information	1607	1609
Safety Related Traffic Information	1607	1609
Dynamic Lane Management	-	-
Variable Speed Limits	-	-
Incident Warning and Management[1)]	1607	1609
Ramp Metering	-	-
Traffic Management Plans for Corridors and Networks	1607	1609

Note:
1) "Incident Warning and Management" is Incident Management only, as incident warnings to the road users are part of the safety related traffic information (to avoid double counting deployments and benefits)
2) "Traffic Condition and Travel Time Information" is Traffic Condition information only, and not travel time information
3) "-" indicates that the NEXT-ITS 2 measure does not include these services

Comment on deployment KPIs: It is important to note that the deployments are primarily focussing on *quality improvements* and not geographical extension of systems and services – which is also obvious when looking at the deployment KPIs.

11.4 Status of the deployments

All deployments within measure 4 are in operation per December 2017

11.5 Technical performance of the systems in operation

The overall technical performance of the systems in operation is very good. Statistics (system logs) in relation to up time (availability) and the response times of the systems and services are very satisfactory. System statistics are being followed as part of the normal operation.

12 Measure 5 – Traffic Management Plans and Ramp Metering Systems, Germany

12.1 Measure descriptions; how NEXT-ITS 2 measures have improved the services

Measure 5 - Traffic Management Plans and Ramp Metering Systems, Germany

The measure includes three Traffic Management Plans and a Ramp metering system on the corridor in northern Germany.

Traffic Management Plan Long Distance Corridor (LDC) North.

The traffic management plan consists of a network control system which comprises the motorways A1/A2/A352/A7/A27/A261 in northern Germany between Hamburg and Dortmund. The system comprises in particular the following components:

- 4 gantries with dWiSta -VMS (Dynamic Directories with integrated Traffic Jam Information) located at motorway A7 junction Walsrode and motorway A1 junction Maschen.
- 4 gantries with dWiSta -VMS (Dynamic Directories with integrated Traffic Jam Information) located at motorway junction A1/A27.
- The necessary monitoring systems (e.g. measurement cross-sections) as basis for controlling the system.

Traffic Management Plan Hannover-Braunschweig-Salzgitter.

The traffic management plan consists of a network control system which comprises the motorways A7, A39, A2 and A391. It manages the traffic on A7 and A2 by the possibility to re-route the traffic between Hannover and Braunschweig in case of congestion, incidents or accidents. The system comprises in particular the following components:

• 10 gantries with dWiSta -VMS (Dynamic Directories with integrated Traffic Jam Information) located at motorway junctions Hannover-Ost (A2/A7), Braunschweig-Nord (A2/A391) and Wolfsburg/Königslutter (A2/A39).

• The necessary monitoring systems (ca. 30 measurement cross-sections) as basis for controlling the system.

Traffic Management Plan A1/A7/A21/B205.

The traffic management plan consists of a network control system which addresses the two main north-south motorways A1 (Hamburg – Lübeck – Fehmarn and further to Denmark) and A7 (Hamburg northbound to Denmark) and two connecting roads (motorway A21, Federal Road B205). The traffic management plan manages the traffic by re-routing in the case of incidents or congestion on one of the motorways. The system already exists and will be enhanced and upgraded according to the increased requirements on modern traffic management. The system will also include travel times and information to the road users. The system consist of:

- Three gantries with dWiSta -VMS (Dynamic Directories with integrated Traffic Jam Information)
- The necessary monitoring systems (e.g. measurement cross-sections) as basis for controlling the system.

Ramp metering systems on A7/A23.

Motorway A23 approaches the Scan-Med-Corridor (motorway A7) in Hamburg. From A23 partly high traffic volumes flow on the corridor. Several ramp metering systems will be implemented on the section of A23 approaching the junction with A7. By these systems the traffic from motorway A23 approaching the corridor can be managed and metered so that the traffic on the corridor (A7) will not be influenced negatively. The system also includes the necessary monitoring as basis for controlling the system.

The measure will improve the quality of continuous traffic management by managing the traffic flow on the Scan-Med-Corridor with a set of traffic management plans and ramp metering systems. In particular:

- Re-routing of traffic in case of congestion, traffic problems, incidents and accidents. In particular the Scan-Med-Corridor will be relieved by re-routing of traffic to other motorway sections.
- Metering of traffic approaching the Corridor by ramp metering systems at motorway junction A23/A7 north of Hamburg and thus positively influencing the urban/interurban interface.
- Improvement of the quality and extent of the traffic management services from an end-user perspective
- Improvement of the quality and extent of the traffic management services from a road operator/traffic manager perspective.

Expected Results:

- Improved traffic flow and better use of existing infrastructure on the corridor
- Implementation of three traffic management plans with several VMS and measurement cross sections.
- Implementation of ramp metering systems

Unfortunately only two of the sub-measures could be finalised during NEXT-ITS 2:

- Network Control System SZ (H-BS-Salzgitter)
- Ramp Metering A23

Both sub-measures have been implemented during NEXT-ITS 2 and are in operation at the end of NEXT-ITS 2.

Two further sub-measures were planned to be carried out within this measure during NEXT-ITS 2, but were delayed respectively could not be taken into account. Both are network control systems with a similar effect on the same services as the Network control system stated above:

- **Network Control System/Traffic Management Plan A1/A7/A21/B205**: This system is being carried out according to plan. However it cannot be stated as NEXT-ITS 2 project, because the coordination and management is carried out by Hamburg which is not a NEXT-ITS 2 partner.
- **Traffic Management Plan Long Distance Corridor (LDC) North**. This system addresses re-routing in Northern Germany. However the implementation is delayed and thus will be carried out after the finalisation of NEXT-ITS 2.

Network Control System/Traffic Management Plan SZ (H-BS-Salzgitter)

The system is located in Niedersachsen on the motorways A2, A7, A39, A37, A391 and Federal Road B6 between the cities of Hannover, Braunschweig and Wolfsburg. The length of the network addressed is about 245,50 km. In the area where the system is implemented the important East-West connections (A2) between Western and Eastern Europe crosses the important North-South connection A7. In the vicinity of the cities of Hannover, Braunschweig and Wolfsburg several smaller motorways around the cities are existing so that re-routing in case of congestion of incidents is possible to improve the traffic situation.

Five large VMS (dWiSta) have been installed at the motorway junctions. The system provides real-time on-trip information on congestion, traffic disruptions (problems, incidents) and re-routing recommendations. It is being operated from the traffic centre and depending from the traffic situation.

Thus the system provides improved real time event information and information on the traffic conditions via the VMS. Re-routing recommendations are integrated so that the road users are informed about the possibly best routes in the case of congestion, incidents, accidents or other traffic problems on parts of the network.

By the information on congestion and possible alternative routes the drivers can assess whether it is advantageous to choose another route. This may depend on the location of the congestion or incident and from the drivers' final destination. As a result parts of the traffic will choose the alternative route which leads to time saving for these drivers. On the original route also a decrease of congestion is expected. The safety (i.e. accidents with fatalities or injured persons) might also be increased because end of queues are always critical points for accidents. However the effects are difficult to assess.

The implementation of the system was finalised end of 2016 and service started with test phases in the middle of 2017.

Ramp Metering A23

On the motorway A23 approaching motorway A7 close to Hamburg often congestion occurs. To improve the traffic situation the respective motorway stretch (16 km length) was investigated and ramp metering systems have been identified as suitable measure. Thus three systems have been implemented via the installation of traffic signals on the on-ramps regulating the flow of traffic approaching the motorway.

The implementation of the system was finalised during 2017 and operation (test phase) started November 2nd of 2017

Service impacts in NEXT-ITS 2 (effect enhanced) are listed in the following table:

Measure 5	Forecast and real-time event Infor-mation Service	Traffic Condition and Travel Time Infor-mation Service	Weath er Inform ation Service	Safety Related Traffic Infor-mation Service	Dynamic Lane Manage ment	Variable Speed Limits	Incident Warning and Manage-ment	Ramp Metering	Traffic Management Plans for Corridors and Networks
Traffic Managemen t Plans and Ramp Metering Systems, DE	-	35 %	-	-	-	-	-	1.5 %	25%

Measure 5 has enhanced or affected services in the following way

2) Traffic Condition and Travel Time Information Service (only on-trip)

Real-time and on-trip travel condition information will allow the road users to adapt their driving behaviour according to the traffic conditions. Furthermore the information on the traffic condition, incidents and accidents and the stated possible re-routing advice allows changing the route. Thus the network can be used in a more efficient way.

An effect of 35% has been estimated.

3) Traffic Management Plans for Corridors and Networks

The network control comprises several motorways which alternatively can be used in the case that one of them is congested or blocked. Depending on the traffic situation information is given (e.g. congestion) with a re-routing advice. The re-routing possibilities of the network control are defined and activated by the traffic centres.

An effect of 25% has been estimated.

4) Ramp Metering

The systems regulate the flow of traffic joining the motorway to avoid large platoons of vehicles entering the motorway leading to critical shockwaves and flow breakdown. The systems thus contribute to the service Ramp Metering and improved traffic flow and reduced congestion.

An effect of 1.5 % has been estimated.

Generally, the network addresses only the motorway stretches where the above mentioned sub-measure have been implemented. Thus a relatively high

12.2 Explain also the relation to NEXT-ITS1 (and if to continue in NEXT-ITS3)

The implementation of both systems has been carried out during NEXT-ITS 2. Preparations (planning etc.) however have been carried out before the start of NEXT-ITS 2.

During NEXT-ITS 3 no substantial work will be carried out for the above mentioned sub-measures. However similar sub-measures (network control systems) with expected similar affects as stated above are planned for NEXT-ITS 3.

12.3 Network affected by the measure, Network description & Network statistics - and assumptions behind the calculations, data sources

The network consists of the motorways affected by the network control system (some 245 km) and the ramp metering systems (16 km).

NETWORK	*2016*	*2017 estimated*
Lenght (km)	261.5	261.5
Vehicle kilometers driven (million/year)	4.764.2	4.883.3
Vehicle hours driven (million/year)	60.0	61.9
Vehicle hours spend in congestion (M/year)	3.6	3.7
Fatal accidents (number/year)	7.9	7.8
Non-fatal injury accidents (number/year)	123.0	127.0
Co2 emissions (million tonnes/year)	1.06822	1.08958

Length (km) has been calculated for the roads influenced by

- Network Control System SZ (H-BS-Salzgitter)
- Ramp Metering A23

Network Control System SZ (H-BS-Salzgitter) addresses directly some 245 km on the motorways A2, A7, A37, A39 and A391 as well as a small stretch on national road B6. The Ramp metering system on motorway A23 addresses some 16 km to the junction with motorway A7

Vehicle kilometers driven (million/year) have been calculated for the respective stretches. The bases are the length of the whole motorway networks of Niedersachsen and Schleswig-Holstein and the total vehicle km driven for these networks. Then the figure for the amount of the vehicle km driven has been calculated by dividing the total figure by the total length and multiplied with the network addressed here.

	Schleswig-Holstein	**Niedersachsen**	**Germany**
Total Motorway Network			
Length (km)	538	1444	12971
vh km driven (in mil/year)	7823	25970,7	237425,4
Network			
Length (km)	16	245.5	
vh km driven (in mil/year)	232.7	4415.4	

Vehicle hours driven (million/year), was calculated from vehicle kilometres driven, with an average speed of 80 km/h.

Vehicle hours spend in congestion (M/year). It was assumed that 6% of all vehicle hours are spent in congestion, thus the vehicle hours spent in congestion was calculated as 6% of all vehicle hours.

Fatal accidents (number/year): The number of killed persons is stated and not the number of fatal accidents. The figures relate to the motorway network only (Source: Statistisches Bundesamt[3]). For the network addressed the figures have been calculated by dividing the number for the whole network by the lengths of the network and multiplying it with the lengths of the network addressed.

Non-fatal injury accidents (number/year). The number of injured persons is stated and not the number of fatal accidents. Furthermore the figure only includes severely injured persons and not slightly injured persons. The figures relate to the motorway network only (Source: Statistisches Bundesamt[4]). For the network addressed the figures have been calculated by dividing the number for the whole network by the lengths of the network and multiplying it with the lengths of the network addressed.

CO^2 emissions (million tonnes/year): CO2 emissions are based on number of vehicle kilometers driven multiplied with an emission factor, which is 167,89 gr/km for private cars (90%) and 742,14 gr/km for heavy vehicles (10%). The figures are taken from the Umweltbundesamt database "Handbuch für Emissionsfaktoren (HBEFA)". The figures have been extrapolated for 2017.

The network includes the following services: Forecast and real time event info, Traffic condition and travel time info, Ramp metering, Traffic management plans

12.4 Deployment KPIs

Comment on deployment KPIs: It is important to note that the deployments are primarily focusing on *quality improvements* and not geographical extension of systems and services – which is also obvious when looking at the deployment KPIs.

For the service "Traffic Condition and Travel Time Information" the coverage of the comprehensive network was 100% already at the end of 2014. For the whole network traffic condition and travel time information is being provided by broadcast.

Traffic Condition and Travel Time Information: Actually the coverage of the comprehensive network was 100% already at the end of 2014 (at least for traffic condition information, and mostly also for travel times (e.g. the broadcasting states something like "due to the congestion the journey takes half an hour longer" etc.). This information is given by e.g. broadcast services for the whole comprehensive network (and also for the main parts of the rest of the network. For the most important parts of the network furthermore information is given roadside by VMS (where motorway control systems are existing). So the new NEXT-ITS 2 information would be additional and of higher quality.

The improvement of the quality is being carried out by additional roadside information of the VMS implemented for the network control system. Thus additionally to the already existing general information on the traffic condition further information on the traffic condition is being made on the stretches where the network control system has been installed, i.e. for additional 245,5 km.

For the services "Ramp Metering" and "Traffic Management Plans for Corridors and Networks" it is somewhat difficult to state percentages of the coverage. Opposite to several other services (e.g.

[3] Verkehrsunfälle 2016, Zeitreihen, 6.7.2017, Statistisches Bundesamt Destatis 2017
[4] Verkehrsunfälle 2016, Zeitreihen, 6.7.2017, Statistisches Bundesamt Destatis 2017

"Traffic condition and travel time information" or "Safety related traffic information" where it is to be aspired to cover the whole network, for Ramp Metering and Traffic management plans it is not.

Ramp Metering: The installation of Ramp Metering makes only sense, if the traffic on the motorway is so high that platoons of vehicles approaching cause disturbances and where the ramp is long enough, so that the waiting vehicles do not cause congestion on the access routes. And of course only on those sections where the benefits exceed the costs. Thus, there are only parts of the network where Ramp Meeting is useful. In the table below the percentage has been calculated for the whole network, actually it would be correct and more appropriate to relate this only to the parts where Ramp Metering is useful. However, this specific network has not been assessed and moreover might change due to changes in traffic. Up to now Ramp Metering is planned and implemented for specific sections where benefits are very likely.

Traffic Management Plans for Corridors and Networks: Also here it does not make sense to provide this service to the whole of the network. First, for some sections there are no suitable alternative roads existing. Second the benefits have to exceed the costs. This means for some sections where alternative roads may exist the problems (congestion, accidents, incidents etc.) did not occur that often so that an implementation of a traffic management plan or a network control system would not economical feasible. Also here in absence of a defined network where such services are useful the percentages have been calculated for the total comprehensive network.

Deployment KPIs

Northern German Comprehensive Ten-T Road network 1780,8	**End of 2014** Length km	**End of 2017** Length km	**End of 2014** %	**End of 2017** %
Road weather monitoring	-	-	-	-
Fixed real-time traffic monitoring	-	-	-	-
Mobile/probe real-time traffic monitoring	-	-	-	-
Forecast and real-time event Information	-	-	-	-
Traffic Condition and Travel Time Information	1780.8	1780.8	100%	100%
Weather Information	-	-	-	-
Safety Related Traffic Information	-	-	-	-
Dynamic Lane Management	-	-	-	-
Variable Speed Limits	-	-	-	-
Incident Warning and Management[1)]	-	-	-	-
Ramp Metering	-	16	0	1%
Traffic Management Plans for Corridors and Networks	314.1	559.6	18%	31%

12.5 Status of the deployments

The Network control system is in operation since the first half year of 2017, the ramp metering system is in operation since November 2017.

12.6 Technical performance of the systems in operation; How the goals were reached by the deployments

The technical performance is expected to be good. However due to the short time since the start of the system specific ex-post evaluations have not been carried out. For both systems test phases giving the opportunity to adapt and optimise the functioning were carried out. For the ramp metering system this phase will last until the end of December.

12.7 References

Verkehrsunfälle 2016, Zeitreihen, 6.7.2017, Statistisches Bundesamt Destatis 2017

13 **Measure 6 – Traffic Centre Schleswig-Holstein, Germany**

13.1 Measure descriptions; how NEXT-ITS 2 measures have improved the services

Measure Description from the Grant Agreement

This measure addresses the traffic centre Schleswig-Holstein. The traffic centre controls and manages all traffic management issues on the Schleswig-Holstein main road network, in particular the motorways A1 and A7 which form an important part of the Scandinavian-Mediterranean Corridor. The traffic management centre is connected to the main ITS systems in Schleswig-Holstein (e.g. motorway control systems, network control systems, wind warning systems etc.).

Within NEXT-ITS 2 the traffic centre will be enhanced and upgraded to fulfil the requirements on modern traffic management. Particular focus is on improvements of the basic data, data processing, data exchange and the integration of further systems into the centre. Of particular interest are the two main motorways A1 and A7 coming from Denmark and forming the Scan-Med-Corridor in Schleswig-Holstein. The measure includes:

- Integration of further ITS systems into the centre by a new central computer, e.g. wind warning system, tunnel control systems from the corridor and road weather systems.
- Furthermore the connection to the German single access point will be realised.
- Improvement of data exchange between the centre and the ITS systems
- Upgrading the centre according to the increased requirements on advanced traffic management and due to the increasing number of integrated systems
- Enhancement of the network of weather and monitoring stations
- Implementation of a road works warning system by a CB-radio system

The measure will improve performance and data processing in the traffic centre, connect to the German single access point for information and management related issues, enhance and improve the monitoring network, improve data exchange to the ITS systems on the corridor, and implement a warning system for road works.

The measure will contribute to the overall objectives by improving the quality, reliability and extent of traffic management services on the Scan-Med-Corridor by:

- Improved continuity of traffic management services, in particular on the northern part of the Scan-Med motorway corridor in Germany and towards Denmark.
- Improved quality and extent of the traffic management services from an end-user perspective
- Improved quality and extent of the traffic management services from a road operator/traffic manager perspective.

Description of improvements due to the NEXT-ITS 2 deployments

Service impacts in NEXT-ITS 2 (effect enhanced) are listed in the following table:

Measure 5	Forecast and real-time event Infor-mation Service	Traffic Condition and Travel Time Infor-mation Service	Weath er Inform ation Service	Safety Related Traffic Infor-mation Service	Dynamic Lane Manage ment	Variable Speed Limits	Incident Warning and Manage-ment	Ramp Metering	Traffic Management Plans for Corridors and Networks

Traffic Centre Schleswig-Holstein, Germany	-	-	-	2.0%	-	-	-	-	-

Measure 6 has enhanced or affected services in the following way

1) Upgrading of the central computer of the traffic centre.

The central computer of the traffic centre has been upgraded by improved software and the integration of further external systems:

- Interface data subcentre DAUZ
- Interface data subcentre NBA A1, A7, A21, B205
- Interface wind warning system
- Interface warning system animals
- Interface: data transmission for traffic situation determination and information
- Improved software for the road weather monitoring

This improved integration of the systems, the easier possibilities to centrally control them and the possibilities share information will lead to improved functioning of the centre. And thus, generally also affects all services which are connected or influenced by the centre. However, this is hardly measurable. It is expected that the following services which are either carried out by the centre or where the centre provides basic information or the data are improved:

- Forecast and real-time event Information Service
- Traffic Condition and Travel Time Information Service
- Weather Information Service
- Safety Related Traffic Information Service
- Dynamic Lane Management
- Variable Speed Limits
- Incident Warning and Management
- Traffic Management Plans for Corridors and Networks

Due to the fact that the expected benefits are hardly measurable they have not been taken into account.

2) CB-Radio warning system for HGV

Accidents with HGV are often severe accidents. Potential dangerous situations occur at the end of queues and at road works. With the provision of information on road works to HGV drivers it is expected that the awareness for such dangerous situations is rising and the risk of accidents will be reduced.

The CB Radio warning system consists of CB-transmitters which are attached to the road works vehicles or trailers. The system sends the information only for a short range (i.e. few km) in the direction of the approaching HGV and it informs only about this specific road works which the HGV are approaching. The system sends in several languages, i.e. in the languages of the countries from which the most HGV come from.

This sub-measure addresses in particular the following service:

- Safety Related Traffic Information Service

13.2 Explain also the relation to NEXT-ITS1 (and if to continue in NEXT-ITS3)

The implementation of a road works warning system by a CB-radio system has been carried out during NEXT-ITS 2. During NEXT-ITS 3 no substantial work is planned for this system.

The Integration of further ITS systems into the centre by a new central computer (e.g. wind warning system, tunnel control systems from the corridor and road weather systems) has been prepared before NEXT-ITS 2 and further systems will be integrated in the future. This is to some extend an ongoing issue.

13.3 Network affected by the measure, Network description & Network statistics - and assumptions behind the calculations, data sources

The improvements in the traffic centre address the whole network of Schleswig-Holstein and in particular the motorways. Thus, the motorway network in Schleswig-Holstein has been used as the relevant network.

NETWORK	*2016*	*2017 estimated*
Lenght (km)	583.00	583.00
Vehicle kilometers driven (million/year)	8.018.58	8.219.04
Vehicle hours driven (million/year)	100.2	102.7
Vehicle hours spend in congestion (M/year)	6.01	6.16
Fatal accidents (number/year)	8.0	9.0
Non-fatal injury accidents (number/year)	154.0	168
Co2 emissions (million tonnes/year)	1.81	1.85

Length (km): The whole motorway network[5] for Schleswig-Holstein has been used.

Vehicle kilometers driven (million/year): The whole amount of the vehicle kilometres driven for the respective motorway network in Schleswig-Holstein has been used[6]. Vehicle hours driven (million/year), was calculated from vehicle kilometres driven, with an average speed of 80 km/h.

Vehicle hours spend in congestion (M/year). It was assumed that 6% of all vehicle hours are spent in congestion, thus the vehicle hours spent in congestion was calculated as 6% of all vehicle hours.

Fatal accidents (number/year): The number of killed persons is stated and not the number of fatal accidents. The figures relate to the motorway network of Schleswig-Holstein only[7]. For 2017 the figures have been extrapolated according to the changes during the last 5 years.

Non-fatal injury accidents (number/year). The number of injured persons is stated and not the number of fatal accidents. Furthermore the figure only includes severely injured persons and not slightly injured persons. The figures relate to the motorway network of Schleswig-Holstein only[8]. For 2017 the figures have been extrapolated according to the changes during the last 5 years.

[5] Fahrleistungen und mittlere DTV-Werte im Bundesfernstraßennetz, Bast 21.9.2017
[6] Fahrleistungen und mittlere DTV-Werte im Bundesfernstraßennetz, Bast 21.9.2017
[7] Ministerium für Inneres und Bundesangelegenheiten Landespolizeiamt (Hrsg.): Verkehrssicherheitsbericht Schleswig-Holstein 2016, März 2017
[8] Ministerium für Inneres und Bundesangelegenheiten Landespolizeiamt (Hrsg.): Verkehrssicherheitsbericht Schleswig-Holstein 2016, März 2017

CO^2 emissions (million tonnes/year): CO2 emissions are based on number of vehicle kilometers driven multiplied with an emission factor, which is 167,89 gr/km for private cars (90%) and 742,14 gr/km for heavy vehicles (10%). The figures are taken from the Umweltbundesamt database "Handbuch für Emissionsfaktoren (HBEFA)". The figures have been extrapolated for 2017.

The network includes the following service: Safety Related Traffic Infor-mation Service.

13.4 Deployment KPIs

Comment on deployment KPIs: It is important to note that the deployments are primarily focusing on *quality improvements* and not geographical extension of systems and services – which is also obvious when looking at the deployment KPIs.

For the service "Safety Related Traffic Information" the coverage of the comprehensive network was 100% already at the end of 2014. For the whole network safety related traffic information is being provided by broadcast and for the critical spots (i.e. high number of accidents and/or often congestion) additionally via the VMS of the motorway control systems. Thus an extension of the geographical area is not possible.

The CB-radio warning system for HGV however is a considerable quality improvement in the network of Schleswig-Holstein by directly and specifically informing HGV drivers approaching to a road works on that roadwork in the drivers languages.

Deployment KPIs

Northern German Comprehensive Ten-T Road network 1780,8 km	**End of 2014** Length km	**End of 2017** Length km	**End of 2014** %	**End of 2017** %
Road weather monitoring	-	-	-	-
Fixed real-time traffic monitoring	-	-	-	-
Mobile/probe real-time traffic monitoring	-	-	-	-
Forecast and real-time event Information	-	-	-	-
Traffic Condition and Travel Time Information	-	-	-	-
Weather Information	-	-	-	-
Safety Related Traffic Information	**1780.8**	**1780.8**	**100%**	**100%**
Dynamic Lane Management	-	-	-	-
Variable Speed Limits	-	-	-	-
Incident Warning and Management[1)]	-	-	-	-
Ramp Metering	-	-	-	-
Traffic Management Plans for Corridors and Networks	-	-	-	-

13.5 Status of the deployments

The a road works warning system by a CB-radio system is in operation, the integration of further ITS systems into the centre by a new central computer has been carried out.

13.6 Technical performance of the systems in operation; How the goals were reached by the deployments

The technical performance is expected to be good. However due to the short time since the start of the system specific evaluations have not been carried out.

13.7 References

BASt, Fahrleistungen und mittlere DTV-Werte im Bundesfernstraßennetz, Bast 21.9.2017

Ministerium für Inneres und Bundesangelegenheiten Landespolizeiamt (Hrsg.): Verkehrssicherheitsbericht Schleswig-Holstein 2016, März 2017

14 Measure 7 - Improve the DATEX-node to meet ITS Directive Action C, NO

14.1 Measure descriptions; how NEXT-ITS 2 measures have improved the services

The Norwegian Public Roads Administration (NPRA) implemented a national DATEX II node for traffic information exchange in 2014. The DATEX-node contains real-time road weather data, incidents, travel times and CCTV. The background for implementing DATEX II was to make the data collected and stored by the NPRA available for internal and external users, and third-party service providers at one single access point.

The real-time information in the DATEX-node is distributed and used internally in the NPRA and externally by service providers. Several systems owned and maintained by the NPRA are integrated with the DATEX-node, and provide data from e.g. road weather sensors and travel time equipment.

Internally in the NPRA the information is e.g. displayed in map-based user interfaces at the five Traffic Management Centers (TMC). The real-time data are available free of charge to service providers after signing an agreement with the NPRA.

The NPRA has also implemented the Delegated Act for Priority Action C, Safety Related Traffic Information (SRTI), under the ITS Directive. The following road safety-related events or conditions are included in the existing version in Norway:

(a) temporary slippery road
(b) animal, people, obstacles, debris on the road
(d) short-term road works
(g) unmanaged blockage of a road
(h) exceptional weather conditions

These categories are available from the DATEX II-node for the TEN-T road network in Norway.

TISA[9] recommends using the attribute "**HeaderInformation: SRTI**" to indicate an increased risk or danger for the drivers. DATEX II (version 2.3) which is the current version used in Norway contains an extension that gives the possibility to tag SRTI messages. However, this requires that the SRTI HeaderInformation is also implemented in the TMC system for traffic incidents.

The NPRA measure in NEXT-ITS 2 has been to prepare for distributing SRTI, according to the Delegated Act for Priority Action C of the ITS Directive. In order to meet the requirements from the ITS Directive, the NPRA has developed a document database (Mongo DB) to enable filtering of SRTI messages from the national DATEX II node.

The information was available in the DATEX II-node prior to the measure, but it will fulfil the demand in the specification for Action C. This will ensure that service providers that distribute the information can receive relevant messages for their services on the TEN-T road network in Norway. It will also display the relevant messages in maps at the TMC more efficiently. The measure will to some extend contribute to reduced latency when distributing the messages, and ensure that the correct messages included in Action C will be distributed to the end users.

[9] TISA - Traveller Information Services Association; www.tisa.org.

The cost for implementation of the measure was 40 K€ (2017). The functionality was deployed during autumn 2017.

Service impacts in NEXT-ITS 2 (effect enhanced) are listed in the following table:

Measure 7	Forecast and real-time event Infor-mation Service	Traffic Condition and Travel Time Infor-mation Service	Weather Information Service	Safety Related Traffic Infor-mation Service	Dynamic Lane Management	Variable Speed Limits	Incident Warning and Manage-ment	Ramp Metering	Traffic Management Plans for Corridors and Networks
Improve the DATEX-node to meet ITS Directive Action C, NO	-	-	-	0.25 %	-	-	-	-	-

Norwegian Measure 7 contributes to the more effective and targeted distribution of SRTI. It is therefore considered to have effect on the SRTI services only, and with no benefit contribution to the other services. The measure has enhanced or affected the SRTI service in the following way:

- less latency
- ensure that the correct messages included in Action C will be distributed to the end users

The SRTI was available in the DATEX II-node also prior to the measure, so it is estimated that the filtering of relevant information will contribute to only 0,1-0,25 % additional impact on road safety as a result of the NEXT-ITS 2 measure.

14.2 Explain also the relation to NEXT-ITS1 (and if to continue in NEXT-ITS3)

The Norwegian measure in NEXT-ITS 2 do not have any direct relation to measures carried out in NEXT-ITS1, but might be continued in NEXT-ITS3.

14.3 Network(s) affected by the measure, Network description & Network statistics - and assumptions behind the calculations, data sources

The DATEX II-node contains real-time traffic and road weather information for all TEN-T network in Norway. The Action C (SRTI) is also prepared for the whole TEN-T road network. It is therefore estimated that the NEXT-ITS 2 measure will have benefit on the TEN-T which constitutes of 4.928 km of roads.

Table. Network statistics in NO networks included in NEXT-ITS 2 benefit calculations.

Services are primarily benefitting the TEN-T road network	**Value 2015**	**Value 2017**
Length (km)	4928	4928
Vehicle kilometres driven (million/year)	12453	12677
Vehicle hours driven (million/year)	N/A	N/A
Vehicle hours spent in congestion (M/year)	N/A	N/A
Fatalities (number/year)	27	26.2
Injury accidents (number/year)	712	706.7
Co2 emissions (million tonnes/year)	N/A	N/A

Length (km) for the 2016 road network has been collected from the National Road Data Base (NVDB). The network at 2017 has been set to be the same as 2016. The relevant network characteristics for TEN-T in 2016 and 2017 are calculated as described below.

Vehicle kilometers driven (million/year) have been calculated as a summary of vehicle kilometers driven in each road section included in the NEXT-ITS 2. NVDB includes length of each road section as well as average daily traffic (ATD), and hence the 2016 kilometers driven was calculated as with the formula ADT*length*365. Annual traffic growth in Norway are expected to be 1.8 % from 2016 to 2017, which is on the same level as annual traffic growth for the last years.

Vehicle hours driven (million/year) and vehicle hours spent in congestion (M/year) is not calculated, since the measure will have impact on traffic safety only.

Fatal accidents (number/year), were collected from the Norwegian national accident database. For fatal accident calculations the real accident numbers for 2014, 2015 and 2016 were used as an average basis to avoid random variability. The 2017 numbers were calculated from the 2016 data with the following assumption: fatal accident rate -4.5% year (according to Elvik et. al. 2015).

Non-fatal injury accidents (number/year), were also collected from the national accident database. For injury accident calculations the real accident numbers for 2014, 2015 and 2016 were used as an average basis. The 2017 numbers were calculated from that data with the following assumption: non-fatal injury accident rate -2.5% year (according to Elvik et. al. 2015).

CO_2 emissions for 2016 and 2017 is not calculated, as the measure is not expected to have any impact regarding emissions.

Databases used for calculating the network length, vehicle kilometres driven and accident statistics are owned and maintained by the Norwegian Public Roads Administration.

14.4 Deployment KPIs + status of the deployments

Deployment KPIs is to assess the % of road network covered by systems for traffic monitoring, management and control and the related services.

No deployment of road-side systems for traffic monitoring, management etc has been a part of the Norwegian measure in NEXT-ITS 2. The deployment KPI for SRTI is shown in the table below. Other Deployment KPIs are not included, because they are not related to the measure.

Norwegian Comprehensive Ten-T Road network 4928 km	**End of 2014** Length km	**End of 2017** Length km	**End of 2014** %	**End of 2017** %
Road weather monitoring	-	-	-	-
Fixed real-time traffic monitoring	-	-	-	-
Mobile/probe real-time traffic monitoring	-	-	-	-
Forecast and real-time event Information	-	-	-	-
Traffic Condition and Travel Time Information	-	-	-	-
Weather Information	-	-	-	-
Safety Related Traffic Information	0	4928	0	100
Dynamic Lane Management	-	-	-	-
Variable Speed Limits	-	-	-	-
Incident Warning and Management	-	-	-	-
Ramp Metering	-	-	-	-
Traffic Management Plans for Corridors and Networks	-	-	-	-

14.5 Technical performance of the systems in operation; How the goals were reached by the deployments

The Norwegian measure in NEXT-ITS 2 aims to improve the distribution of SRTI (Action C) on the TEN-T road network in Norway. The DATEX II-node operates 24/7, and contains relevant real-time traffic and road weather information. The filtering functionality implemented by the measure helps service providers to identify relevant messages to be distributed on their services. The overall technical performance of the systems in operation is good.

15 References for impacts of NEXT-ITS2 services

Forecast and real-time event information service

Real-time traffic information about problems and hazards on the road network to drivers before the trip and during the trip to in-vehicle receivers enable the drivers either to avoid the problem by e.g. changing their route or to be better prepared for the problem by increasing their awareness and alertness. Real-time information on slipperiness and other road weather related problems has been estimated to reduce the risk of injury accidents in adverse conditions by 8 % on main roads and 5 % on minor roads in Nordic conditions (Rämä et al 2003). Warnings of slowly moving traffic ahead have been found to improve drivers' situation awareness when approaching the end of the queue (Nowakowski 2011).

Several studies have been carried out on the RDS-TMC (Radio Data System – Traffic Message Channel) service providing event information to drivers with specific RDS-TMC receivers. While there exists little explicit evidence of safety impacts, studies indicate that the service is affecting driver behaviour in the assumed direction. A study in UK showed that 45 % of drivers with an RDS-TMC receiver had changed route due to on-trip RDS-TMC messages at least once. On the basis of information received before the trip, 23 % of the drivers had changed their plans (Tarry & Pyne 2003).

Fontes et al (2014) explore the usage and availability of information provided by ATIS on a regional scale in order to quantify the impact of traffic incidents on energy consumption and emissions (NO_x, HC, PM, CO and CO_2) levels. Several scenarios with different degrees of information (through the use of ATIS) were analysed using a simulation platform which combined a mesoscopic traffic model (DTALite) and a road emissions methodology (EMEP/EEA). This platform was then used to assess the impact of a traffic incident which can occur in two different road types: a highway and a motorway. With this work it has been demonstrated that:

- In a regional road network the use of ATIS can allow, for each incident, a reduction in emissions and energy consumption on the routes where they occurred, up to 2% for motorway and highway ;
- A non - linear trend was found between the availability of information and the impact on emissions and energy consumption. If the information increases from 25 % to 50%, the impact increases or decreases 0.3 -0.7%, but when the information rises from 50% to 75%, the impact is typically half of the value previously yielded.

Therefore, having access to pre - trip information might not always bring benefits especially in large networks where traffic conditions could change between the departure time and the arrival time. Thus, the results obtained with this paper suggest that the usage and availability of the information provided by ATIS, namely in a regional scale must be carefully analysed and planned. In fact all the efforts to provide a highly amount of information to the driver (>50%) may not be translated in relevant emissions benefits. As a result, a definition of an area of impact must be previously defined in order to control the environmental and economic costs.

Klunder et al. (2009) reviewed the models that are suitable to evaluate the impacts of three classes of ICT - related measures (eco -solutions, traffic management, Advanced Driver A ssistance Systems, ADAS) on road traffic CO_2 emissions. At the macro level, CO_2 emission models based on traffic situations are used to assess the effects of traffic management measures on traffic intensity. An example is the ARTEMIS model (Andrè et al., 2 008), adopted for the evaluation of the Stockholm congestion charge. A sufficiently large variety of traffic situations – necessary to ensure a proper validation – is still lacking, although the extension of micro models might provide the possibility to impo rt different traffic situations. The evaluation of the effects deriving from the traffic management measures is also possible with instantaneous emission models combined with microscopic traffic simulations.

References:

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Commission, Directorate General Energy and Transport, TEMPO Programme.

Traffic condition and Travel time information service

Klunder et al. (2009) reviewed the models that are suitable to evaluate the impacts of three classes of ICT -related measures (eco -solutions, traffic management, Advanced Driver A ssistance Systems, ADAS) on road traffic CO_2 emissions. At the macro level, CO_2 emission models based on traffic situations are used to assess the effects of traffic management measures on traffic intensity. An example is the ARTEMIS model (Andrè et al., 2 008), adopted for the evaluation of the Stockholm congestion charge. A sufficiently large variety of traffic situations – necessary to ensure a proper validation – is still lacking, although the extension of micro models might provide the possibility to impo rt different traffic situations. The evaluation of the effects deriving from the traffic management measures is also possible with instantaneous emission models combined with microscopic traffic simulations.

Siegener et al (2000) studied the information and management systems using VMS in Germany. The route information and management systems decreased the risk of road accidents by 15% and the risk of severe injury accidents by somewhat more, between 9 and 36 %. The impacts of the system depend on the quality of the traffic management system and the level of traffic volumes. On roads with high traffic volumes, the numbers of accidents were 22 – 64 % lower than before the implementation of the system. On roads with low or moderate volumes, the changes in accident numbers were statistically insignificant.

Objective of the study by Penttinen et al (2014) was to investigate the use and impacts of travel time information in Finland, especially in the largest cities. The information was collected by internet survey during May 2013. A representative sample of 1018 drivers responded the questionnaire. The most important motivation to get travel time information was to optimize the route choice. In addition, drivers were interested in the reasons for the delays in traffic. Travel time information was estimated to have greatest impacts on the timing of the trip and the route choice. In addition, it was reported to affect travel comfort. The most common sources of travel time related information were still radio and various VMS's, however, the use of personal devices and hence applications providing real-time traffic information has increased during the past few years, and those newer sources were considered as important as the more traditional ones by those who use them. The users also estimated travel time information quite valuable for them, especially on longer trips and in capital area.

References:

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Safety related traffic information

Heinig et al (2007) studied the impacts of Dynamic traffic management systems and local danger warnings, which were aimed at increasing the safety and flow of traffic in cases of disturbance caused by incidents, congestion and adverse weather. The systems are operated automatically, semi-automatically or manually from traffic control centres based on fixed monitoring systems or mobile sensors (FCD etc.) on location. The systems employ Variable Message Signs or VMS to give the information to the drivers. Three categories of VMS exist based on the types of messages given: 'regulatory messages', 'danger warning messages' and 'informative messages'. Local warning systems use danger warning messages.

The systems improve road safety by making the drivers more aware of incidents and other problems on the road section immediately ahead. Current evidence from accident studies indicates that roadside local warning systems reduce all injury crashes by -1 to -5% and all fatal crashes by slightly more. Environmental impacts of the system can be expected to be positive but very limited.

The aim of Aittoniemi (2007) study was to assess the potential impacts of real-time personal road traffic in-vehicle information systems on injury accidents in such a way that the results can be used when deciding on the participation of the public sector in implementing road traffic in- vehicle information systems in Finland. Additional aims were to determine other impacts of in-vehicle information systems on traffic flow, emissions and choice of travel mode. A literature review and an expert survey were used to measure the safety impacts. The results indicate that a weather and road condition warning service and a well-implemented route and service guidance system would improve traffic safety and reduce the number of injury accidents in Finland. Incident warning systems do not have a notable safety impact in due to the small number of incidents on Finnish roads, but their primary purpose is to improve traffic flow.

References:

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Weather information service

Cooper and Sawyer (1993) examined an automatic fog-warning system in England, the results indicated a reduction in the net mean speed of approximately 3 km/h when “Fog” warning was displayed.

A Dutch fog warning system studied by Hogema et al (1996) including a text warning (“fog”) and dynamic speed limit VMS signs on a motorway, reduced speeds in fog by 8 to 10 km/h, although in extremely dense fog, the system had an adverse effect on speed. This was due to the too high lowest possible speed limit display in the VMS (60 km/h). A more uniform speed behaviour was obtained due to the introduction of the system.

A Finnish study (Luoma et al., 1996) showed that slippery road warning VMS decreased mean speeds by around 1 – 2 km/h when the signs were lit. The system was also shown to affect the 40 direction of attention to find cues showing potential hazards, and to make passing behaviour more careful indicating an even larger positive impact on safety than that due to lower speeds (Luoma, Rämä, Penttinen & Harjula, 1997). In addition, Rämä et al () found real-time information on slipperiness and other road weather related problems to reduce the risk of injury accidents in adverse conditions by 8 % on main roads and 5 % on minor roads in Nordic conditions.

A variable speed limit system integrated with a fog warning system reduced the number of injury accidents on a German motorway by ca. 20% (Balz & Zhu 1994), and a variable speed limit system integrated with a slippery road warning system on a Finnish motorway by ca. 10% (Luoma et al 1997). Both studies reported significant reductions of mean speeds (3 to 9 km/h) in adverse weather conditions, and the latter also a significant decrease in speed variation.

Sandberg et al (2014) studied the use and impacts of Finnish road weather information. Based on the internet survey and internet panel of this study, about 70 % of road users have used weather information services at least once a week during winter time. Road users seek weather information especially from internet and television. Interviews of freight companies showed that freight companies and taxi and bus operators use most common weather information services and many companies were not even aware of weather information services offered by Finnish Transport Agency. Weather information before the trip affects especially the allocated travel time and change of departure time. During the trip the common impacts on driver behavior were decreased number of overtakings, increased following distance to vehicle in front, and reduced driving speed. Changes that are made before the trip allow driver better possibilities to adapt the driving speed suitable for weather conditions resulting in lower risks. The effects of weather information on pedestrians and cyclists during the trip were found to be increased observation of road surface and decreased speed. Pedestrians also report understanding better that drivers may not be able to stop quickly. Weather information helps freight companies to maintain customer satisfaction and minimize the risk of accidents.

References:

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Dynamic lane management

Andersen and Dörge (2016) studied dynamic lane management including hard shoulder running in Denmark. Taking into account all the analyses performed the overall key result of the pilot trial is that use of the hard shoulder as a traffic lane in the morning rush hour has generally improved traffic flow, increased capacity, reduced travel times, reduced the variation in travel times, resulted in shorter queues and shorter duration of queues. Further, it has reduced traffic on the local roads along the M13. It is too early to point out any effects on traffic safety, but so far there is no indication neither on positive nor negative effects. In addition, the road users are in general satisfied with the introduction of hard shoulder running (HSR) on the M13.

What can be learned in practice about the local solution and its functionalities? The very positive overall key results are mentioned above and this section will elaborate further on various results. In 2013 before the HSR, the average travel time was 22 minutes on a 15 km section from Allerød to Motorring 3. The local solution has reduced the average travel time by 1-3 minutes and up to 5 minutes towards junction 6 (12 km). The busiest part of the morning rush hour with queuing and very low speeds start 20 minutes later and stops 20 minutes earlier with HSR. Traffic volume on the motorway between 7 am and 8 am has increased with 18 % ~ 700 vehicles/h, from 3800 to 4500 vehicles/h with HSR. Traffic has shifted from the local roads to the motorway, from 1150 to 750 vehicles/h (7 am to 8 am). The changes in traffic volumes mean that bottlenecks in the southern end of the HSR section have become more visible. There are some challenges with more queueing on the exit at junction 6 after the HSR section and at the exit towards Motorring 3 further south on the M13. The Danish Road Directorate is looking into what can be done. If the capacity and traffic flow can be improved at these two locations, the positive effects from the HSR trial are expected to increase even more. A socio-economic assessment conducted according to the DRD guidelines and model for cost-benefit analysis of ITS systems with a 10-year time frame gave positive results: Investment costs: 3.1 M €, Annual operation costs: 0.1 M €; Net present value: 8.0 M €; Internal rate of return: 26.8 %. (Andersen and Dörge, 2016)

Note that the assessment includes effects on traffic flow only. Safety and environmental effects are not included. Some potential for improvements have been identified: 1) More information to the road users on how to use and not use HSR is needed; 2) Possible adjustments of road markings and VMS displays should be considered; 3) If possible, capacity further south of the HSR section on the M13 and at exit 6 should be improved, 4) Added value can be achieved if the system and the VMS are used for other purposes than HSR, 5) Further analysis of the safety related aspects of HSR should be carried out.. (Andersen and Dörge, 2016)

The overall result that HSR as a concept is an effective and beneficial measure is assessed to be transferable to other sites with similar bottleneck problems, but of course dependent on the local network and traffic conditions and other local characteristics. The detailed results are not transferable to other sites, since they depend to a large extent on the local factors. I.e. Reductions in average travel time: 5 – 14 % and on one specific stretch (towards junction 6) it is 23 %. (Andersen and Dörge, 2016)

An UK study, Highways Agency, 2009 study reported in 2DECIDE-toolkit shows In all respects, that ATM has met the objectives of the Highways Agency to improve journey time reliability; the journey time variability reduced by 22%. In addition, the goal was to reduce congestion -> 7% additional road users encountered no congestion. Evaluation has proven a 9% increase in road capacity and during peak periods it has shown that there is some spare capacity. Average journey times improved where demand outstretched capacity. This equated to a reduction in journey time of 24% northbound and 9% southbound or 4 minutes and 1 minute. In addition, Personal Injury Accidents have dropped from 3.17 to 1.83 per month during hard shoulder running. Vehicle Emissions and Air Quality: C02 -4 - 5%; NOx have decreased by 4-5%; PM10 reduction is 10%

Another UK study (Active Traffic Management - Dynamic Speed and Hardshoulder Operation, UK, 2008) reported in 2DECIDE-toolkit reports a project with both hard shoulder running and VMS. The systems have been implemented on the M42 between Junctions 3A and 7, near Birmingham with the total daily traffic varying between 50,000 and 75,000 vehicles per direction. This section of motorway is 17km in length and is part of a major strategic TERN route which allows traffic to connect across all parts of the UK and as such is subject to high Average Annual Daily Traffic (in the region of 130,000 vehicles). The M42 is a dual 3-lane motorway, where each running lane varies in width from 3.3m to 3.7m, with a hard shoulder on both carriageways ranging between 3.3m and 3.7m. Lane widths were modified in places during the construction period to enable the hard shoulder to be widened enough to be used as a running lane.

Timing of evaluation: March 2002 to March 2003 - Data collection for "before" case; March 2003 to July 2005 - Data collection during construction; January 2006 to September 2006 -3 Lane Variable Mandatory Speed Limit data collection; September 2006 to September 2007 - 4L-VMSL data collection. The 4 Lane Variable Mandatory Speed Limit Operational Regime was introduced on 12th September 2006. Since then, the performance of 4L-VMSL on the M42-ATM section (J3a-J7) has been closely monitored. The performance of 4L-VMSL is assessed between October 2006 and September 2007. This time period is assessed against No Variable Speed Limits, whilst its performance over the period between January and August 2007 is assessed against 3L-VMSL. Project was completed in 2007. (Active Traffic Management - Dynamic Speed and Hardshoulder Operation, UK, 2008)

The analysis of speed differential between lanes and the lane utilisation analysis has shown that 4L-VMSL smoothes the traffic operation on the M42-ATM section which can potentially lead to improved road safety and also has improved the distribution of traffic between lanes, which is an indication of a better utilisation of the motorway. Capacity of link or junction increased between 7 - 9%; Number of Traffic accidents (per traffic unit) reduction 40 - 60%; Reduction of noise 10%; Fuel consumption/CO2 emissions reduction 4%, NOx reduction 5%. (Active Traffic Management - Dynamic Speed and Hardshoulder Operation, UK, 2008)

The Business Case Study by Highways agency (2007) for Controlled Motorways showed that, although the costs of Controlled Motorways outweigh the benefits for the M25 Junction 15 to 16 section, there could be benefits from applying Controlled Motorways at other sites. The primary benefits identified through this study are: 1) Smoother and more reliable journeys in certain periods; 2) Reduction in stress for drivers; 3) Reductions in the number and severity of accidents; 4) Reductions in traffic noise, vehicle emissions and fuel consumption; and, 5) Improved driver behaviour.

Some of these benefits (e.g. a reduction in accidents) have a monetary value. Others (e.g. more reliable journeys, reduced driver stress and environmental benefits) do not currently have a monetary value, but they are still important benefits. If all the benefits are taken into account, the case for installing Controlled Motorways at further sites is likely to be more favourable, providing that the proposed sites have suitable characteristics as identified within this study. Guidance on the nature of sites where Controlled Motorways are most likely to be cost effective has been developed, along with a Generic Assessment Tool to aid the decision making process. Those benefits that could be taken forward did not outweigh the cost of implementation on M25 J15 to 16. However, the Generic Business Case as applied to the example site suggests that the introduction of Controlled Motorways at other sites could prove economically viable. Caution is required with interpretation of the results, since they are highly sensitive to small variations in traffic flows. (Highways Agency, 2007).

SERTI projects (2010) Main objective of the system is to divert through-traffic between Mannheim and Stuttgart in case of incidents and traffic overload from the normal route (A6, A81) to the alternative route via A5 and A8 by route recommendations. The system has been operational since 1989. The Baden-Wuerttemberg Traffic Control Centre Ludwigsburg monitored and controlled the system. The associated variable direction signs are installed on the A8 in the approach from the Eastern direction before the motorway interchange Leonberg; on the motorways A5 and A6 they are installed on the approach from the Northern direction before the motorway interchange Walldorf. Due to many years of operation, the control model as well as the associated variable direction signs were outdated and error-prone; moreover it was difficult to repair due to lacking spare parts. Therefore a modernization of first the variable direction signs was foreseen, followed by the control model.

A pre-assessment (ex-ante evaluation) was done in 2003/2004 as part of the conceptual design. A benefit-cost ratio of 1.95 results for the network control system Leonberg-Walldorf. Network control system Leonberg – Walldorf (implementation of VMS/ dWiSta panels) (A5, A6, A8 and A81 between Stuttgart, Karlsruhe, Walldorf and Heilbronn) Total benefits from reduction of travel time and increase in safety. The estimated Benefit-cost ratio was 1.95. (SERTI, 2010)

A French study from 2011 reported in 2DECIDE-toolkit concerns the Implementation of a dynamic lane control system for tidal flow, St. Nazaire Bridge. The Saint-Nazaire Bridge was opened in 1975 and is the only crossing of the lower Loire estuary. It carries heavy traffic flows (approx. 27 000 vehicles per typical weekday, 34 000 vehicles at summer holiday peak periods), in particular tidal commuter traffic to the city of Saint-Nazaire (on the north bank of the river) from mainly residential towns on the south side of the River Loire. The bridge involves a relatively steep incline on each side to the apex in the centre of the river crossing. The approach roads on either site are 2+2 dual carriageway expressways. Previously the bridge was 3 lanes wide, with a fixed formation consisting of two lanes climbing towards the middle of the bridge and one lane descending in each direction. Therefore, in each direction, two lanes merged into one a short distance before the apex (centre) of the bridge. This led to congestion leading up to the lane-drop on the bridge itself, particularly in the direction of peak traffic flow where long queues were common. The bridge speed limit was 90km/h and there was also a sub-standard verge on each side of the roadway for use by cyclists (dangerous because of the road speed and the fact that the cycle lane was too narrow). The main impact was travel time reduction. It reduced in average by 29%.

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SERTI 2010. Network Control Leonberg - Walldorf. Project Evaluation Summary. EasyWay Region SERTI. Project Location: Baden-Wuerttemberg (motorways A 5, A 6, A 8, A 81 between Stuttgart, Karlsruhe, Walldorf and Heilbronn).

Variable Speed limits

Andersen and Dörge (2016) studied Danish VMS impacts. The evaluation covers dynamic lane management too. Taking into account all the analyses performed the overall key result is that the variable message signs have a positive effect on the traffic flow on the M3. Especially on the travel times which in average are shorter with the VMS in operation. The evaluation also shows that the capacity during peak hours is higher with the VMS in operation, specifically in the maximum 15-minute peak. In addition, the road users are in general satisfied with the service that the VMS information provides. Before the evaluation was done a number of evaluation questions to be answered in the evaluation were formulated. In the following the results per question are summarised.

Is the motorway utilization better with VMS in operation?

The motorway is better utilized with VMS in operation. The analyses of traffic in the maximum 15-minute peak on the most congested segments of M3 show that traffic throughput has increased 1.4 -1.9 %. Hence, the capacity is higher with VMS in operation which means that peak hours begin a little later when VMS are in operation. In the two hours morning and afternoon peak periods the traffic volumes on the M3 are about the same in 2014 and 2015. An exception is the northbound direction during the morning peak in which the traffic volume has increased by 2.3 % in 2015 (without VMS in operation). The reason for this increase is assessed to be a general increase in traffic volumes. (Andersen and Dörge, 2016)

Do the VMS reduce travel times?

On the entire 13 km evaluation stretch the travel time is 0.5 to 1.5 minute faster with VMS in operation. In average, during normal traffic conditions, the travel time during peak hour is 10-14 minutes without VMS in operation. The change in travel time is largest in the southbound direction during the afternoon peak and in the northbound direction during the morning peak. As mentioned above, the traffic volume has increased by 2.3 % in northbound direction during morning peak and the observed change in travel time may partly be due to more congestion. The traffic volumes in southbound direction (both morning and afternoon peak) and as well northbound during the afternoon peak are unchanged, thus the general increase in traffic volume is assessed not to have an impact on the changes in travel time. An analysis of the duration and extension of queues shows that there is less queueing with VMS in operation. When the VMS are not in operation, the speed is below 40 km/h approximately 10 % of the time during peak hours. With VMS in operation, the speed is below 40 km/h only 6 % of the time during peak hours. The time period with free flowing traffic (speeds above 80 km/h) is longer with VMS in operation, 78 % versus 68 %. (Andersen and Dörge, 2016)

Do the VMS improve traffic safety?

From the analyses performed it cannot be concluded whether traffic safety has changed. The primary reason is that the time period without VMS in operation has been too short for assessing significant changes in the accident rate. On the M3 relatively few accidents are registered by the police. Experiences show that in accident analyses a 5-year before and after period is needed. However, the VMS system has only been shut down for less than half a year, so the data set is not comprehensive enough to draw conclusions on traffic safety. Accidents with limited material damage, e.g. rear end collisions, are not registered systematically by the police. Therefore, it has not been possible to draw conclusions in relation to this type of accidents either. The speed towards a recurrent bottleneck has been tested as an indicator of the accident risk. It is assumed that when road users are not warned about a queue ahead of them, they drive faster towards the rear end of the queue. It means that the higher the speed towards the rear end of the queue is, the higher the accident risk will be. The analysis has led to ambiguous results and therefore no conclusion can be drawn from it. (Andersen and Dörge, 2016)

Summary of the main results:

Capacity increase: 1.4 % - 1.9 %; Average travel time reductions: 4 – 15 %; Reduction in queues, duration and extension: Speeds < 40 km/h reduced from 10 % to 6 % of time, Speeds > 80 km/h increased from 68 % to 78 % of time; Traffic accident reduction: 0 % (data set not comprehensive enough to draw clear conclusion) (Andersen and Dörge, 2016)

Another Danish study by Dörge (2013) also studies the impacts of dynamic lane management and variable speed limits. The traffic amount has increased by 1 % in the northern direction and 2 % in the southern direction; the measurement point is at Gl. Holte (bottleneck) and the increase is from the before situation without ITS (February to June 2011) to the after situation with ITS (same time period in 2012). Based on the traffic amounts measured, a modelling analysis of average travel time has been made by using the FREEVAL traffic model: The northern direction from Lundtofte to Gl. Holte: Improvement/reduction in average travel time in afternoon peak period: 3 – 10 %; The southern direction from Kokkedal to Gl. Holte: Improvement/reduction in average travel time in morning peak period: Up to 17 %.

The modelling approach has been used in relation to travel time because GPS data were not available yet. Several calculations were made, some resulting in larger impacts than others and hence an interval has been estimated. The time spent in queues (speed below 40 km/hour) has been calculated based on actual data from several measurement points: The northern direction from Lundtofte to Gl. Holte: Improvement/reduction in time spent in queues in afternoon peak period: 5 % ; The southern direction from Kokkedal to Hørsholm Syd: Improvement/reduction in time spent in queues in morning peak period: 12 %. All improvements calculated are from a before situation without ITS to an after situation with ITS. (Dörge, 2013).

Analyses of traffic safety have been performed preliminary, but the results are very uncertain due to a short after period (with ITS) of only one year. The analyses show that the number of personal injury accidents has been almost halved (from before to after). This reduction is bigger than the general reduction in the number of accidents that has taken place in the same time period (in the entire country). The number of accidents with material damage has increased, which may be caused by the improved traffic flow with increased speeds (/reduced travel time in peak hours) on the section; and perhaps the camera surveillance will reveal other causes. However, it should be noted that the results are uncertain due to statistically small numbers in the analyses. (Dörge, 2013)

Summary of the main results: Average travel time reductions: 3 – 17 %; Reduction in time spent in queues: Speeds < 40 km/h reduced 5 – 12 % (5% in afternoon peak, 12 % in morning peak)

A Dutch study (2010): Dynamic speed limits - evaluation of field trials (rain A12 Bodegraven-Woerden) reported the impacts of Dynamax project. In order to gain more knowledge about dynamic speed limits, the project "Dynamax" was carried out in The Netherlands. On the highways A1, A12 and A58 field trials with various dynamic speed limit applications were carried out. The effects on traffic flow, air quality /noise levels and road safety were investigated. The effects on driver behaviour and driver acceptance for dynamic speed limits are also investigated. An site-specifc algorithm -using forecasts of the national whether service- triggered signs on dynamic route information panels (DRIP) above the road to display the maximum speed limit: 80 or 100 in stead of 120 km/h.

An important topic regarding traffic behaviour and human factors is the reduced compliance to speed limits below 100 km/h. This is particularly attributable to situations where the speed limit does not match the In order to gain more knowledge about dynamic speed limits, the project "Dynamax" was carried out in The Netherlands. User acceptance of the measure is high: 78% is (very) positive. Of the interviewees 83% is positive towards an introduction on the measures in the rest of The Netherlands. For the use of dynamic speed limits to increase traffic safety in rainy conditions, the deployment of the rain algorithm resulted in a reduction (12 km/h at speed limit 100 km/h and 21 km/h at speed limit 80 km/h) of the average velocity.. This reduction was significantly larger than the speed adjustment road users themselves apply in the rain (3 km/h to 8 km/h). (2DECIDE-toolkit: Dutch Dynamax 2010).

Another Dutch study related to dynamic speed limits investigated the effects on traffic flow, air quality /noise levels and road safety. The effects on driver behaviour and driver acceptance for dynamic speed limits are also investigated. The use of dynamic speed limits on the A58 near Tilburg focused on improving air quality. When the level of particulates approached the daily target, the speed limit was reduced from 120 to 80km/h. NOx -18%; Side effects are an increase in travel time by 10 to 15% and a limited (positive) impact on traffic safety and noise emissions. No additional traffic jams will emerge. (2DECIDE-toolkit: Dutch evaluation of DSLs on A58)

A Swedish study (2DECIDE-toolkit) evaluated the impacts of road weather controlled variable speed limits. The speed adaptation was clearly improved by the VSL system at Halland and Blekinge. The average speed was 15-20 below the level that drivers chosen during corresponding adverse conditions with traditional fixed signs. The overwhelming problem concerning results for weather-controlled VSL is to "control" the weather. Measurements were made in order to cover two consecutive winter seasons. There may however be rather great variations between years. Weather station data were used to distribute traffic between different weather conditions in the before situation. In order to reduce the influence of the weather the same distribution was used in the after situation. Later, it was recognized that data from the weather model in the after situation gave a more reliable distribution of traffic between different slippery road conditions. It was then dedicated to use data gathered in the after situation also for the before situation. Still, there is a problem to compare the before and after situations. Bad weather, defined as friction below 0.4 occur 10-15% of the time during the winter in Sweden. In order to estimate the benefit of weather controlled VSL it is highly important to correctly identify black ice and compact ice conditions with friction below 0.2, when the accident ratio is at least 15 times higher than in dry conditions. For the Blekinge site calculations have been made to estimate representative predictive costs. The Blekinge VSL had a reported investment cost of 4.3 MSEK, maintenance cost of 1.2 MSEK and operational cost of 2.5 MSEK during the life cycle. The total LCC cost is 8.0 MSEK. The socio economical calculations for Halland reveal a benefit cost ratio of +1.6. Thus the investment is beneficial provided that correct speed limits are displayed during 80 % of the time when adverse weather conditions occur. This accessibility level however is not sufficient to make the investment in Blekinge beneficial (benefit cost ratio +0.8). Impact Description; The indicator represent the percentual change of the number of actually injured and killed persons 2.5 years before and after the introduction of VSL. Number of Traffic accident fatalities (per traffic unit) ; reduction of about 40%, Speed reduction (-20km/h speed limit) -> -4 - -5km/h average speed of traffic flow.

A series of Swedish impact evaluations of traffic controlled variable speed limits were summarized to 2DECIDE-toolkit. Trials with Variable Speed Limits (VSL) for different applications were carried out by the Swedish Road Administration in 2003 - 2008. The goal has been to demonstrate if and how VSL can contribute to a better speed adaptation in a cost-efficient way. Traffic controlled VSL is one application area. The speed limit is temporary adjusted downwards on major roads when traffic becomes dense and queue is building up. Although the number of people killed and injured in road traffic is comparably low in Sweden (471 killed in road traffic 20071) this number is still not considered acceptable, and there is a constant ambition to decrease it to the greatest possible extent. VSL could be one conceivable means to this end. The overall problem behind the VSL initiative is the very poor compliance with speed limits in Sweden, and the negative effect this has on road safety and traffic throughput. Speed limits that are perceived as well measured, with regard to road standard and traffic conditions, have a higher likelihood of being met with appliance than limits that seems overly cautious. With VSL there is a possibility to prescribe mandatory speed limits that adapt to traffic conditions, with decreasing speed limits in dense traffic while still maintaining higher allowed speeds when conditions are good.

Variable speed limits seem to be an effective means for handling congestion and growing queues especially where the speeds tend to suddenly fall dramatically. This is especially valid on busy arterials with recurring capacity and traffic safety problems. Sections that are curvy, hilly and have road passages breaking the sight line could be suitable candidates for VSL. A reasonable strategy would be to identify spots on major arterials where sudden speed drops often occur and where queues start to build up. On sections where queues during rush hours already have developed, the influence from VSL is rather small. In such cases it is more suitable with dynamic queue information since the drivers have to adapt their speed to the movement of the queue anyhow. When conditions are good (meaning low traffic flow) it should be possible to increase the maximum permitted speed limit. This speed limit should be displayed on fixed speed signs (switched off VSL). Lower speed limits are displayed on illuminated VSL at adverse conditions. International experiences suggest that surveillance is an effective means of making the drivers adjust their speed to the displayed level. This lead to less speed variation and by that a more consistent traffic flow, effects that is expected to be durable. The information to the drivers about the functioning of the VSL systems need to be enhanced and widely distributed. It is also important to spread this information to the police, road authorities and other parties dealing with road traffic issues.

Congestion. the travel time from Mölndal to Tingstadstunneln (12 km) was shortened according to car following-studies in dense traffic by about 5 %. Including queue situations the reduction in travel time is 15 %. (Refer to report for details and figures). The introduction of VSL in Mölndal and Tingstadstunneln has led to an increased average speed at moderate and dense traffic flow. It has also contributed to less frequently occurring congestion situations. Reduction in average travel time, including queue situations; -15 %; Reduction in average travel time, excluding queue situations; -5 %; Safety: A follow-up for Mölndal after two years of operation show that the accident ratio. The number of accidents per million vehicle kilometres has been reduced by 20 %. Accident data from E18 Norrtäljevägen indicate that there is no difference before and after the introduction of VSL. The statistical basis however is too small to permit definite conclusions.

Socio economic calculations were carried out for the Mölndal site. Time consumption on the section was reduced by an economical value of 36 mill SEK/year or by 15 %. As a basis for estimating the safety impacts. two years of statistics before implementation and two years after were used. These data show a 20 % decrease in the number of injury accidents. Since figures are shaky due to the short follow-up periods. the assumption was made that VSL contributes to half of that reduction (10 %). This corresponds to a value of 2 mill SEK/year. According to the Samkalk program the environmental costs increase by 5 % meaning 2.6 mill SEK/year. The above calculated figures together with an estimated total cost (investment and operation) of 37.2 mill SEK. during a 20-year-period, give a likely benefit-cost ratio of more than 10. The implementation in the Tingstadstunneln is also estimated to be a profitable investment. However E18 Norrtäljevägen is probably not beneficial with the current VSL configuration. (Calculation to euro/year: For year 2007: 1 Euro = 9,2501 SEK. I.e 36 mill SEK = 3,8915 mio. Euro)

References:

2DECIDE-toolkit, including the following studies:

- *A Dutch study; 2010: Dynamic speed limits - evaluation of field trials (rain A12 Bodegraven-Woerden)*
- *A Dutch study, 2010: Dynamic speed limits - evaluation of field trials (A58)*
- *Road weather controlled variable speed limits, Sweden, Swedish study, 2009*
- *A Swedish study (number of studies), published 2009; Traffic controlled variable speed limits, Sweden*

*Andersen C.L., Dörge, L. (2016). A Danish MCS deployment, Evaluation summary of "Effect of variable message signs on the Motorring 3", August 2016. (*Summary of a Danish evaluation report issued in September 2015, Rambøll)

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Incident warning and management

Incident warnings are provided by roadside VMS or beacons, and via radio and cellular information services. Studies usually show accident reductions on the IWS (Incident Warning System) equipped motor way sections. The whole range of the effect on the total number of injury accidents is from –35 per cent to + 9 per cent, where the largest reductions may include bias caused by the regression-to-the-mean effect. The effects are more beneficial on secondary accidents (Kulmala, Fránzen & Dryselius, 1995). According to Elvik et al. (1997), rear-end injury accidents have decreased as a result of queue warning systems on motorways whereas the number of rear-end accidents resulting in property damage only have increased. Japanese field tests (Makino 2004) of a local obstacle and congestion warning VMS system on a motorway indicated a 45% reduction in accidents after the VMS was installed, but the effect is probably biased due to the regression-to-the-mean effect.

A Driver Warning System providing speed limit information and hot spot warning features was analysed in a study carried out in Germany. The results of the study showed that the system reduced driving speed by 5%. The system was found to have potential to reduce the number of fatalities by 2.1–10.7%, fatal accidents by 1.7–8.7% and serious injury accidents by 0.7–3.6% depending on the expected market penetration between 13–65% in 2016 and the quality of implementation. (Heinig et al. 2007)

Safety can be improved not only by just reacting swiftly to incidents but also by preventing them through harmonisation of the traffic flow. This can be accomplished by ramp control (or ramp metering), lane control, route diversion schemes, and in general traffic management. Safety is also expected to be improved as a result of replacement of manual toll collection with automatic tolling on motorways due to the elimination of traffic channelling at toll plazas as well as of the possible queues and unnecessary stops (Bandmann & Finsterer, 1997).

Lane control has little effect on injury accidents (Perrett & Stevens, 1996 and Elvik et al., 1997). Ramp control is considerably more beneficial to safety, the accident reduction on equipped motorways being up to 10 % as such, and more than 15 % as a part of an integrated motorway management system (Federal Highway Administration, 1997a; Perrett & Stevens, 1996).

Route diversion schemes are beneficial to safety only when the diversion does not increase exposure (driving distance) too much and does not divert traffic to roads with higher accident risk. Unfortunately, this is very seldom the case. The opposite case is shown by for example Lashermes and Zerguini (1997).

Route information and management systems employing VMS in Germany decreased the risk of road accidents by 15% and the risk of severe injury accidents by somewhat more, between 9 and 36 %. The impacts of the system depend on the quality of the traffic management system and the level of traffic volumes. On roads with high traffic volumes, the numbers of accidents were 22 – 64 % lower than before the implementation of the system. On roads with low or moderate volumes, the changes in accident numbers were statistically insignificant. (Siegener et al 2000)

Influencing vehicle speeds with the help of variable speed limits has been tried especially in connection with weather-related traffic management systems by lowering speed limits in adverse conditions. A variable speed limit system integrated with a fog warning system reduced the number of injury accidents on a German motorway by around 20 % (Balz & Zhu, 1994), and a variable speed limit system integrated with a slippery road warning system on a Finnish motorway by around 10 % (Rämä, 2001). Both studies reported significant reductions in mean speeds (3 to 9 km/h) in adverse weather conditions, and the latter also a significant decrease in speed variation. An accident study showed that weather-related speed control reduced injury accidents by 13 % in winter and 2 % in summer on sections, where the control system was automatic and of good quality. Manually operated systems, however, were estimated to result in increased accident risks (Rämä

& Schirokoff 2004). A variable speed limit system has been found to reduce the number of injury accidents by 20% on a Swedish motorway (Lind & Lindkvist 2009). This result was based on a before-and-after study but the results of the study were not statistically significant.

A Dutch fog warning system including a text warning (“fog”) and dynamic speed limit VMS signs on a motorway, reduced speeds in fog by 8 to 10 km/h, although in extremely dense fog, the system had an adverse effect on speed. This was due to the too high “lowest possible speed limit” display in the VMS (60 km/h). A more uniform speed behaviour was obtained due to the introduction of the system (Hogema, van der Horst & van Nifterick, 1996). Variable speed limits have also been applied by schools, resulting in a 20 per cent accident reduction (Elvik et al., 1997).

In addition to speed control, the high accident risks caused by adverse weather conditions can be decreased by providing information, warnings and support to road users, but also by combating weather problems with the help of winter maintenance. A Finnish study (Rämä et al., 1996) showed that slippery road warning VMS decreased mean speeds by around 1–2 km/h when the signs were lit. The system was also shown to affect the direction of attention to find cues showing potential hazards, and to make passing behaviour more careful indicating an even larger positive impact on safety than that due to lower speeds (Luoma, Rämä, Penttinen & Harjula, 1997).

The automatic fog-warning system on the M25 motorway in England displays the “Fog” legend on roadside matrix signals. The assessment of this system showed that the net mean vehicle speed reduction was around 3 km/h, when the signals were switched on as a result of the formation of fog (Cooper & Sawyer, 1993). Collision warning systems are probably beneficial to road safety in the fog (Saroldi, Bertolino & Sidoti, 1997).

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Ramp metering

Ramp metering is a good example of an ITS service, the effects of which depend strongly on local conditions as well as the way in which the control is implemented. With optimal control and sufficient ramp lengths to avoid queues spilling onto the surrounding road network, the impacts can be highly beneficial. At locations with poor control strategies and too short ramps, the impacts can be negative, even though the main road benefits tend to usually outweigh the problems caused to minor road traffic.

It should also be noted that it was not clear in many studies whether the results were for the whole corridor and network or just the main highway, on the ramps of which the meters have been installed. The former case would be the correct way to deal with all relevant impacts.

Vehicle hours driven: Assuming that the location is chosen reasonably well, the effect on the vehicle hours driven on the corridor in question are likely in the range of -5 to -20%. In Nordic conditions, where the traffic volumes are lower and the expected hours of ramp meter use are shorter than in most of the studies, the expected benefits on the annual level are likely lower, perhaps from -1 to -8%.

Vehicle hours driven in congestion: The impacts are larger as the meters are used especially during the congested hours of the day. In Nordic conditions, the expected change could be in the range from -5 to -20%, dependent on the site.

Fatal and injury accidents: The safety improvements reported in literature are quite varied with crash reductions ranging from 5 to 37%. As above, the crash reductions in Nordic conditions are likely to be smaller, in the range of 1 to 12%, depending on the accident type distribution of the corridor.

CO2 emissions: The impacts of emissions have been reported at a few studies only, and with contradictory results ranging from reduction of 9% to increase by 4%. The effects in Nordic conditions will be smaller, perhaps -2 – +1%.

Cambridge Systematics 2001. Twin Cities Ramp Meter Evaluation. Executive summary prepared for Minnesota Department of Transportation (Pursuant to Laws 2000: Chapter 479, HF2891) by Cambridge Systematics, Inc. February 1, 2001. 20 p. http://www.dot.state.mn.us/rampmeter/pdf/executivesummary.pdf

In 2000, an experiment was mandated by the Minnesota State Legislature in response to citizen complaints and the efforts of State Senator. The study involved shutting off all 433 ramp meters in the Minneapolis-St. Paul area for eight weeks to test their effectiveness. The study concluded that when the ramp meters were turned off freeway capacity decreased by 9%, travel times increased by 22%, freeway speeds dropped by 7% and crashes increased by 26%.

However, ramp meters remain controversial, and the Minnesota State Department of Transportation has developed new ramp control strategies. Fewer meters are activated during the course of a normal day than prior to the 2000 study, some meters have been removed, timing has been altered so that no driver waits more than four minutes in ramp queue, and vehicles are not allowed to back up onto city streets. [Wikipedia]

Haj-Salem, H.; Farhi, N.; Lebacque J.P. 2012. Field Evaluation Results of new Isolated and Coordinated Ramp Metering Strategies in France. IFAC Proceedings Volumes, Volume 45, Issue 6, 23–25 May 2012, Pp. 378-383.

The field tests were carried out in the southern part of the Ile de France motorway network A6W. This site is the most critical par of the Ile de France motorway network. Three different ramp metering control strategies of ALINEA, VC_ALINEA, and CORDIN were alternated and compared to the No Control situation. ALINEA was found to decrease the total time spent in the network by 10% and to increases the mean speed by 5%. The VC_ALINEA control provided better results than ALINEA in term of total time spent (-12%). The total distance travelled decreased by 5% whereas for ALINEA, the TTD decreases was 2%. The CORDIN strategy provided changes of -12% for time spent, 0% for distance travelled, and +11% for mean speed. Accident risks were estimated to decrease by 18 – 22% for the different controls. The fuel consumption changes compared with the No Control case were estimated to be -8%, -5%, -8% for ALINEA, VC_ALINEA and CORDIN respectively. The emissions were found to decrease for all control strategies. In particular, the HC and CO indices were reduced by 6%, 9% and 7% for ALINEA, VC_ALINEA and CORDIN respectively.

Haugen, T.; Giæver, T. 2001. Trafikkavvikling E6 Hedemark – Utforming og evaluering av tilfartskontroll ved Kolomoen [Design and evaluation of ramp metering at E6/rv. 3 at Kolomoen, Norway]. SINTEF rapport STF22 301304.

The evaluation dealt with a ramp meter at intersection in a rural environment, where rv. 3 (two lane road) merge onto another main road E6 (two lane road). Design of ramp metering on the entry ramp from rv. 3, road side equipment, algorithms, testing and evaluation. Long queues and a lot of delay, especially on Sunday afternoons were frequent in the before situation. Most delays occurred on the E6. Travel times and delays was measured on a total distance of 27 km. First measuring point was 9 km upstream the ramp metered intersection and last measuring point was 18 km downstream. Maximum hourly traffic volume down stream of intersection varied from 1100 to 1300 veh/hour.

The results showed that the total delay decreased from approx. 900-1400 veh. hours for the situations without ramp meter and to approx. 90-100 veh. hours for the situations with an active ramp meter. The highest traffic volume was registered on Sunday 13th of August, which probably contributed to the high total delay measured. On one Sunday (10th Sept.) the defined managing criteria was not followed, and too much traffic was allowed to enter E6 from rv. 3. This resulted in queues on E6 and an increased total delay (365 veh. hours). For the current intersection, and the days with assumable similar pre-requisites and conditions, the total delay was reduced from an average of 895 vehicle hours to an average of 95 vehicle hours. This gives a reduction in total delay of 90 %.

Highways Agency 2008. Ramp Metering Operational Assessment. Traffic systems and signing, Issue A, April 2008. 58 p. http://webarchive.nationalarchives.gov.uk/20101110234459/http://www.highways.gov.uk/knowledge/documents/Ramp_Metering_Operational_Assessment.pdf

The operation of ramp metering was studied at 30 sites as a before and after study utilizing mostly monitoring systems existing at the sites. The evaluation could not be carried out at few of the sites due to roadworks and other confounding factors. The results demonstrate that ramp metering has generally had a positive impact on journey times and traffic flows on the mainline carriageway when installed at carefully selected locations on the motorway network. The delays ramp metering can have upon on slip road traffic is more than outweighed by the benefit received by vehicles on the mainline carriageway, with a close link between the level of savings on the mainline and the level of delay on the slip road. The overall change in peak period traffic flows observed on the mainline after the installation of ramp metering varies by site with individual changes in traffic flow ranging from -2% to +30%. Despite the increases in traffic flow, the implementation of ramp metering has resulted in overall journey time savings on the mainline during peak periods ranging from -5% to +40% with an average journey time saving for mainline traffic of 13% across all sites evaluated. The average on-slip delay per vehicle with ramp metering operational ranged from 8 seconds to 78 seconds; however the sites with the highest delay on the slip road in general also delivered the highest benefit on the mainline.

Lee, Chris; Hellinga, Bruce; Ozbay, Kaan 2006. Quantifying effects of ramp metering on freeway safety. Accident Analysis & Prevention, Volume 38, Issue 2, March 2006, Pp. 279-288.

This study presents a real-time crash prediction model and uses this model to investigate the effect of the local traffic-responsive ramp metering strategy on freeway safety. Safety benefits of ramp metering are quantified in terms of the reduced crash potential estimated by the real-time crash prediction model. Driver responses to ramp metering and the consequent traffic flow changes were observed using a microscopic traffic simulation model and crash potential was estimated for a 14.8 km section of I-880 in Hayward, California and a hypothetical isolated on-ramp network. The results showed that ramp metering reduced crash potential by 5–37% compared to the no-control case. It was found that safety benefits of local ramp metering strategy were only restricted to the freeway sections in the vicinity of the ramp, and were highly dependent on the existing traffic conditions and the spatial extent over which the evaluation was conducted. The results provide some insight into how a local ramp metering strategy can be modified to improve safety (by reducing total crash potential) on longer stretch of freeways over a wide range of traffic conditions.

Liu, Chiu; Wang, Zhongren 2013. Ramp Metering Influence on Freeway Operational Safety near On-ramp Exits. International Journal of Transportation Science and Technology, Vol 2, No 2, 2013, Pp. 87 – 94.

Ramp metering has been widely installed in urban areas where congestion on a freeway or an expressway may occur recurrently during weekday peak periods to enhance mainline throughput and reduce system-wide delay. These operational benefits may also help reduce vehicular emissions and improve air quality in urban areas. However, the impact on traffic safety due to ramp metering hasn't been explored in details before. Supported by physical understanding and arguments, we characterize the ramp metering influence on freeway safety by examining vehicular collisions near on-ramp exits within the ramp meter operating hours before and after

the activation of the ramp metering. Collisions for a sample of 19 operating ramp meters along several freeways in northern California were collected and organized to show that ramp metering can help reduce freeway collisions at the vicinity of on-ramp exits. It was found that the average reductions on freeway collisions in the vicinity of an on-ramp exit are around 36%. Although most of the reduced collisions belong to the property damage only category, a 36% reduction shows the significant safety benefit of ramp metering. The traffic congestion induced by each collision, especially during peak hours when ramp metering is in operation, could last for an hour or two. Consequently, ramp metering must be contributing to the reduction of non-recurrent congestion in addition to mitigating recurrent congestion, which is better documented. This study strongly supports the implementation of ramp metering in California.

Middelham, Frans; Taale, Henk 2006. Ramp Metering in the Netherlands: An Overview. IFAC Proceedings Volumes, Volume 39, Issue 12, January 2006, Pp. 267-272.

For ten on-ramps with ramp metering a successful assessment study was done. For two on-ramps, even two studies were conducted. The effect on capacity can vary between no effect and an increase of about 5%. The speed on the motorway increased in all cases, but the order varies substantially. Dependent on the situation and the objective of ramp metering, the use of the on-ramp decreases strongly. Because the speed on the motorway increases, travel time decreases, at least in those cases were this indicator was analysed. The calculation of total delay in vehicle hours does not happen often (only in 3 studies). On the other hand red light violation is studied in almost all assessments. If there is no clear bottleneck, this percentage increases to about 15%. If a red light camera is installed, only about 2% to 3% risks a fine.

Qin, X.; Lee, C. 2007. Evaluation of safety benefits from isolated ramp meters. Proceedings: 14th World Congress on Intelligent Transport Systems. Beijing, China, 9-13 October 2007, Volume 5, 2007, Pages 4077-4090.

Transportation agencies around the country have implemented a variety of measures to mitigate freeway traffic congestion and improve safety, including ramp metering. Historically, most ramp meters were predominantly placed on high volume corridors in large cities and usually at consecutive freeway entrance points to maximize the benefits of ramp metering. As such, many evaluation efforts focused on the benefits of large systems. The potential benefits from a small number of ramp meter installations for urban freeways in mid or small size cities is seldom studied and examined. The study focuses on assessing ramp metering safety benefits by the limited number of ramps, a total of five metered on-ramps along the Highway 12/18 in the City of Madison, Wisconsin. The evaluation results present noticeable safety impacts brought by the ramp metering. A naïve before-and-after analysis using crash data at the metered on-ramps demonstrates fewer crashes and lower crash rates during the peak period with new meters in operation and the off-peak with ramp geometric improvements only. The safety benefits obtained from a before-and-after analysis with comparison sites are even more pronounced. Further analysis is conducted to evaluate crashes by manner of collision. Rear-end and sideswipe same direction (SSS) crashes gained the largest reduction during the meters in operation. The analysis of the field data confirms that in general, ramp metering has had a positive safety impact on the Madison urban freeway although the system consists of limited numbers of ramp meters.

Taale, Henk; Schuurman, Henk 2015. Effecten van benutting in Nederland Een overzicht van 190 praktijkevaluaties [Effects of utilization in the Netherlands: An overview of 190 practical evaluations]. TrafficQuest, May 8, 2015.

The evaluation summary concludes on a maximum 5% increase in highway capacity with an average of 2%. Ramp metering has increased speeds by 3 km/h on average on the highway close to the meters, resulting in shorter travel times. The number and severity of shock waves were also reduced. Ramp metering was found to result in 1 – 4% higher emissions.

Öörni, Risto 2004 Economic feasibility of road and public transport ITS applications in Finnish conditions. Ministry of Transport and Communications Finland, FITS Publications 35/2004.

The literature study looked also in the effects and socio-economic feasibility of ramp metering in Finnish conditions. Based on considerable efficiency benefits, the report estimated the benefit to cost ratio to be in the range from 4 to 27 at locations, where ramp metering would be feasible to implement.

Traffic management plans for corridors and networks

EU-project SILENCE (UK, 2008)

Reducing noise due to road traffic in urban areas can be achieved through different measures of traffic management such as: -reducing and enforcing speed limits (and the involved infrastructure modifications : roundabouts, chicanes, bumps and cushions, junction design), -bans on trucks, -city logistics, -congestion charging. This report refers to different studies made on these different measures. It presents with more details the results of noise mappings in Bristol and Munich aimed at testing some of these measures: lower speed limits on urban motorways and in specific zones, HGV Restriction / Redirection in selected areas.

Noise emissions are highly connected with traffic volume, traffic composition, speed and driving patterns (e.g. acceleration). The HGV traffic has an important impact, as they represent peaks in the emitted noise which may annoy and disturb the population along the road. This study aims to lower noise perception due to road traffic in urban areas through traffic management measures and driver assistance systems. It emphasizes the fact that individual measures may result in reductions which are barely noticeable, but when several measures are combined, substantial reductions may be achieved.

The individual measures may result in reductions which are barely noticeable, but when several measures are combined, substantial reductions may be achieved. The actual effect of these measures on the noise level truly depends on local traffic conditions. The experience shows that the use of variable signs for posting speed limits or informing drivers of their speed is more effective than static signs when it comes to reducing driving speed. By changing the design parameters of a green wave scheme, a reduction of the average speed by 10 to 15 km/h may be expected, which corresponds to a noise reduction of 2.5 to 3 dB.

A Dutch study, 2003; Cost effectiveness utilization measures (from 2DECIDE-toolkit)

This study describes both measures to physically increase road capacity, for instance by adding lanes, as ITS systems that can help to increase the capacity of the existing network. ITS applications discussed include DRIPS, ramp metering, traffic signals and homogenization measures on speed. The cost effectiveness of both adding physical capacity and using existing infrastructure more effectively with help of ITS systems is assessed in this study. The study is focused on the Netherlands as a whole. Main finding of the study is that the number of Vehicle Loss Hours between 1995 - 2000 would have doubled (+98%) if no measures where taken. However, with the combination of measures taken (Both on physical capacity as ITS solutions) in the programme 'Verkeersbeheersing 1995 -2000' the increase in Vehicle Loss Hours is convened to 40%. Most substantial in these road capacity gains (in absolute terms) are the increases in physical capacity (increases road capacity with 36% in sample period), however an ITS solutions such as DRIPS also leads to an increase in the road capacity of 5% for a fraction of the costs.

The results of ITS systems on increasing road capacity vary greatly depending on location. Besides the outcomes of any CBA are by definition depended on the inputs of critical values and ratio's such as the discount rate and the value of a Vehicle Loss Hour (which is set constantly at 15E for the whole period). For the effects of the measures on the reduction in the Vehicle Loss Hours, the McKinsey factor is used, which is widely regarded as a outdated estimation factor, however it is the best available estimation factor.

Lessons learnt and factors of success: The key lessons learnt from this study are that both measures to physically increase road capacity, as ITS applications are of vital importance to increase the road capacity on expressways. From an Cost-Benefit perspective the measures have high yields, resulting from the fact that the benefits greatly exceed the costs.

Methodologies Used The methods used are: -Calculating the loss in Vehicle Loss Hours to asses the increase in roadcapacity -Using the average costs of a Vehicle Loss Hour the socioeconomic impacts of the roadcapacity increasing measures are calculated.

Indicator road capacity change: Traffic signals 5; DRIP's +5; Ramp metering +4. Combining several measures leads to a maximum increase of +10. Time loss caused by insufficiency of network capacity; h/veh/day; Percentage Change: -17.5 % (=improvement)

A German study, 2003: Effects of corridor control systems on capacity of motorways and stability of traffic flow (from 2DECIDE-toolkit)

Some German motorways are equipped with Corridor control systems CCS, which aim on increasing traffic safety and performance. The study's objective is the determination and quantification of possible benefit components of CCS in regard to improving traffic flow. Up to now examinations of the effectiveness of CCS focused mainly on the reduction of accident figures, where impressive results could be achieved by corridor control systems. Mainly the high number of accidents occurring due to critical weather or surrounding conditions could get reduced considerably (e.g. the number of accidents occurring due to the presence of fog decreased by 80%). The effects of CCS on traffic flow have not been examined into detail yet. Several studies were carried out regarding the harmonization of traffic flow in combination with examinations of accidents. These investigations assessed both the temporal and the spatial harmonization effects of the CCS. There exist only few knowledge on the effects of CCS on capacity and performance, although the first investigations dating from the 1970s and the 1980s already prove the positive effects of these systems. Although early research done in this direction showed a stabilization of traffic flow by CCS, despite this even a smaller number of reports covers this topic. The objective of the presented research work is the examination of the effects of CCS with respect to traffic flow in the sector of the capacity limit, to determine existing mechanisms of action and to survey these mechanisms in an assessment procedure.

The study proves that CCS can lead in different ways to improved traffic flow and this way to reduced travel times for road users. In the case of high traffic volumes (which regularly reach or exceed the capacity limit) along a route, a noticeable economic benefit can be generated. With regard to the magnitude, this benefit reaches the value of the benefit generated by the minimization of the number of accidents, which is considered so far. Therefore this should be taken into consideration additionally for investment decisions. It is proven, that operational measures can ease congestion situations. The implementation of CCS should be especially considered if for financial reasons constructional measures are not feasible (or only in the far future). In cases a route is overloaded temporarily and only seldom (e.g. because of holiday traffic or special events) already in the planning phase of the extension measures the increase of capacity of a temporary unblocking of shoulders should be considered. Basically emphasis should be put on the fact that with optimized control algorithms as well as improved information and a more frequent control of the road users the potential of CCS could be optimized further. A comparison of the capacities of the examined cross sections did not show any significant differences.

As a basis for this study an empiric consideration is selected, that is, measurements of traffic flow along several road stretches are procured and evaluated. The measurement data are examined with regard to capacity, performance and the homogeneity and stability of traffic flow. The comparison of routes equipped with CCS with routes without CCS assessed the effects of these systems. For every cross-section data on traffic flow for an interval of one minute for every lane over a time period of 14 days could be examined. For cross-sections along routes with CCS the displays of the variable message signs were processed and connected to the measured traffic flow. Only the data of those cross sections which showed both comparable route, weather and traffic conditions and a comparable traffic volume have been selected

Measurement data from 9 corridors and 244 cross-sections have been analysed within this research project. The data set covers numerous implementation areas of CCS (two / three-lane cross-sections, routes in conurbations / connecting routes, flat / hilly topography). An automated selection algorithm analysed the cross-sections' measurements on their data quality. The cross-sections have been evaluated with respect to the objective of the examination. From the complete data set have been selected only the comparable cross sections.

Capacity of link or junction increased by 25%

a German corridor project: Long-distance Corridor Demonstration Project, 2008 (from 2DECIDE-toolkit)

Within the LDC Project an initiative about network management has started between member states and regions coming from CENTRICO, CORVETTE, VIKING and SERTI. Inside this initiative three LDC pilot corridors were implemented and evaluated in 2006/2007. An "intermodal/interregional strategy manager" based on a server to server/client architecture was developed and used. This paper deals with the evaluation results of re-routing-measures and the organisational framework on these LDC-corridors. The aim is to determine the effects of traffic management and to study the effectiveness of the procedures used.

A technical tool for strategy co-ordination is required and necessary in light of increased number and scope of strategies. The current form of Strategy-Client E-mail based system was seen as not totally acceptable. E-mail based communication was seen in many cases as not practicable in terms of operator not being present in front of the terminal, the lack of secure interface of the Internet-based tool to the existing IT networks of the traffic control centres and the need to provide/have additional information on the traffic situation before response and activation permission. An addition to ISM (Interregional Strategy Manager) tool, known as Operator View, having more content user interface and allowing easier user interaction and faster communication and response time on an Internet-basis was seen as helpful and a useful addition by the operators in the West and North Corridors that used it. An integrated open source design of the user interfaces and communication protocols was seen as essential for future implementation of the ISM with clear integration with the existing systems at the traffic control centres. Tailoring of the user interfaces to the requirements and the resources of the individual traffic control centres in addition to a uniform software for the validation and activation of the network strategies was recommended.

A good preparation framework in order to persuade the various regions on the feasibility of co-ordinated strategy management to improve traffic flows and capacities in their own networks and to allow for timely incident response is an important success element. In addition, common understandings of the terminologies, criteria and a consensus-based approach for activation and de-activation of strategies is required.

High quality evaluation with good data quality. RELIABILITY: The trial period varied from 10 months in the West Corridor to 8 months in South Corridor to 4 months in North Corridor. Apart from the North Corridor which had only 2 strategy activations, the number of activations in both the West and South Corridors was statistically valid to estimate consistent estimates of cost-benefits on the basis of re-routed traffic and the level of traffic information, in addition to operator experiences.

Travel time savings for re-routed traffic in response to major incidents were estimated. Around 85-95 % of total benefits arose from travel time savings. (Refer to cost-benefit information for actual travel time savings)

Reduction of environmental damages due to re-routed vehicles was estimated. Due to the relatively short time frame of re-routing measures on average of 4 hours for most activations. the level of long-distance diverted traffic was not significant enough to enact a high environmental aspects. with most environmental impacts in the level of 4 % of total benefits. (Refer to Cost-benefit information for more information)

References:

2DECIDE-toolkit, 2017. (http://www.its-toolkit.eu/2decide/node/36) , (version: August 25th, 2017)